FIG.1

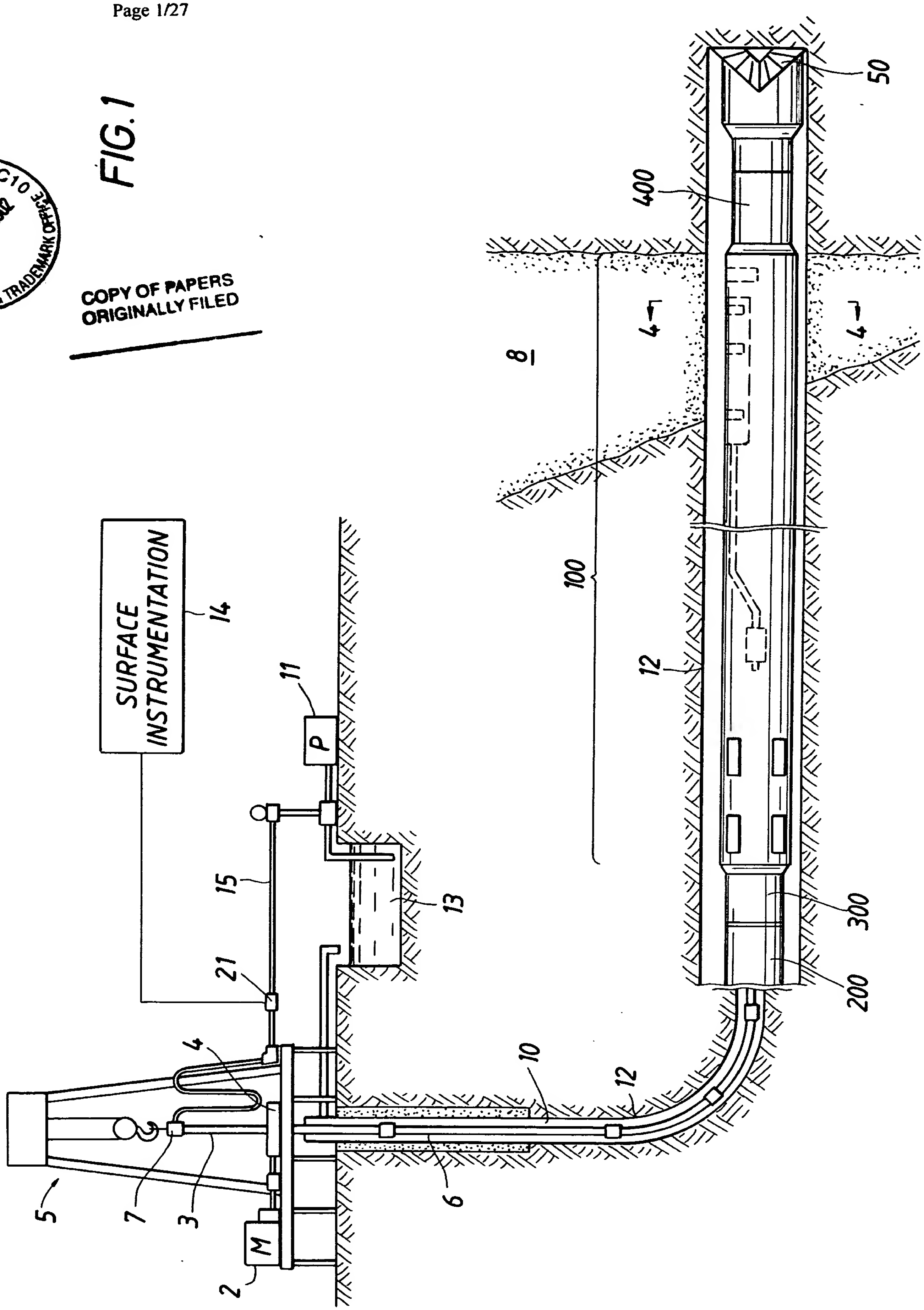
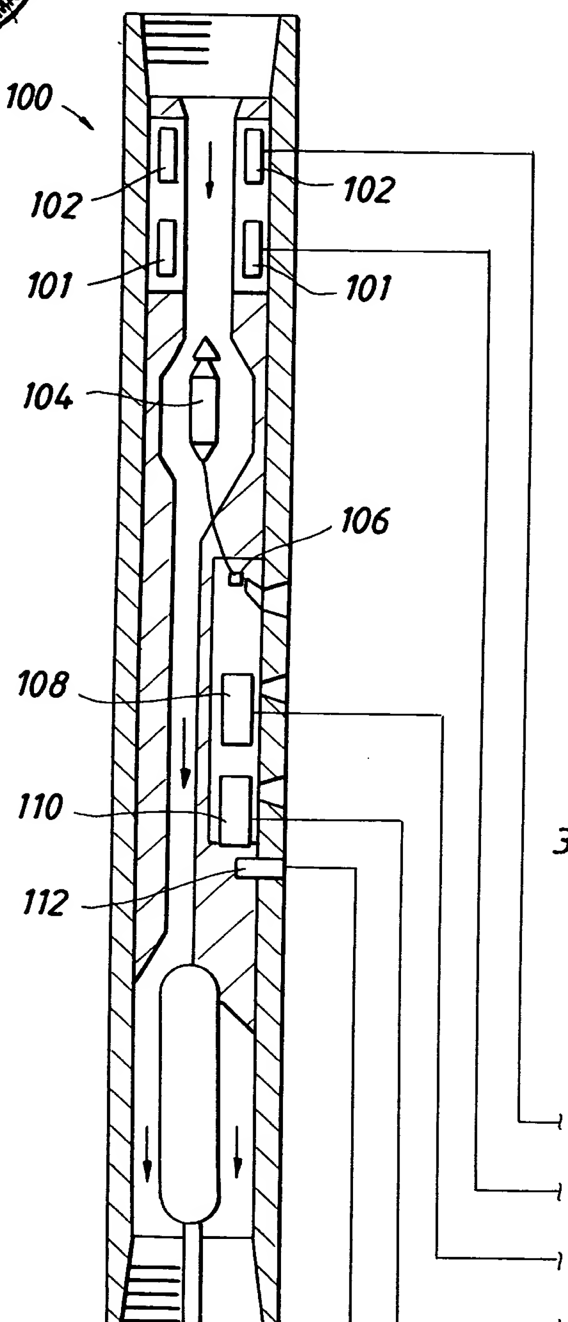

SURFACE INSTRUMENTATION
14
P
11
15
13
21
4
5
7
3
M
2
6
10
12
200
300
100
12
8
4
4
400
50

FIG. 2


100
102
102
101
101
104
106
108
110
112

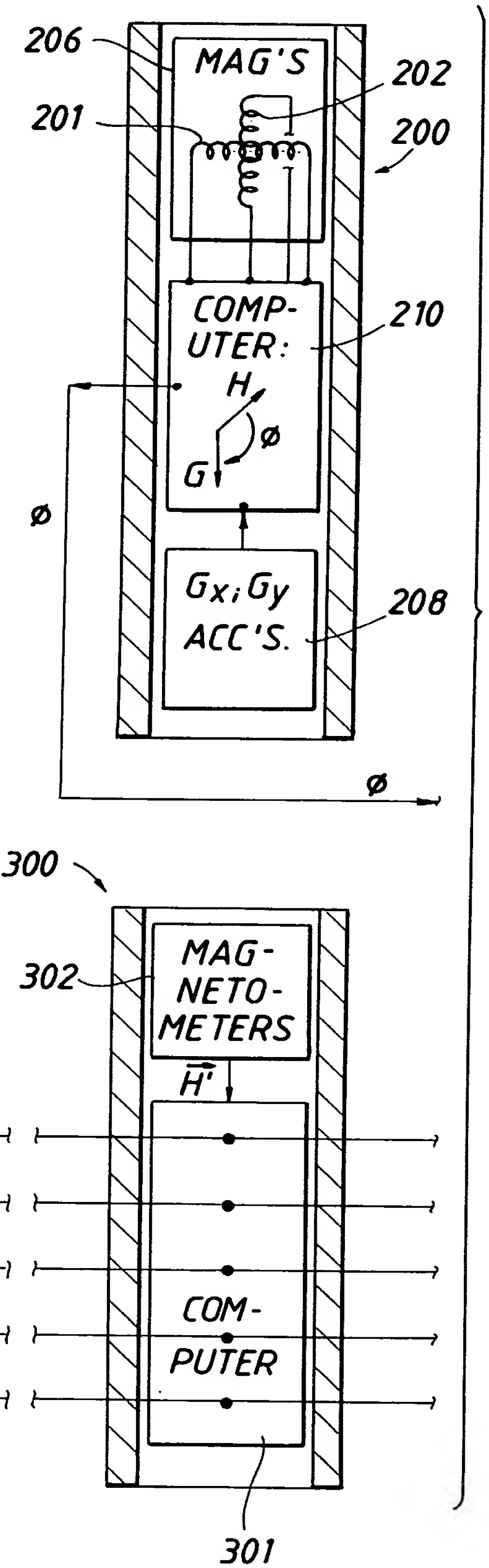

206
MAG'S
202
201
200
COMP-
UTER:
H
ø
G
210
ø
Gx; Gy
ACC'S.
208
ø
300
MAG-
NETO-
METERS
302
H'
COM-
PUTER
301

FIG. 3A

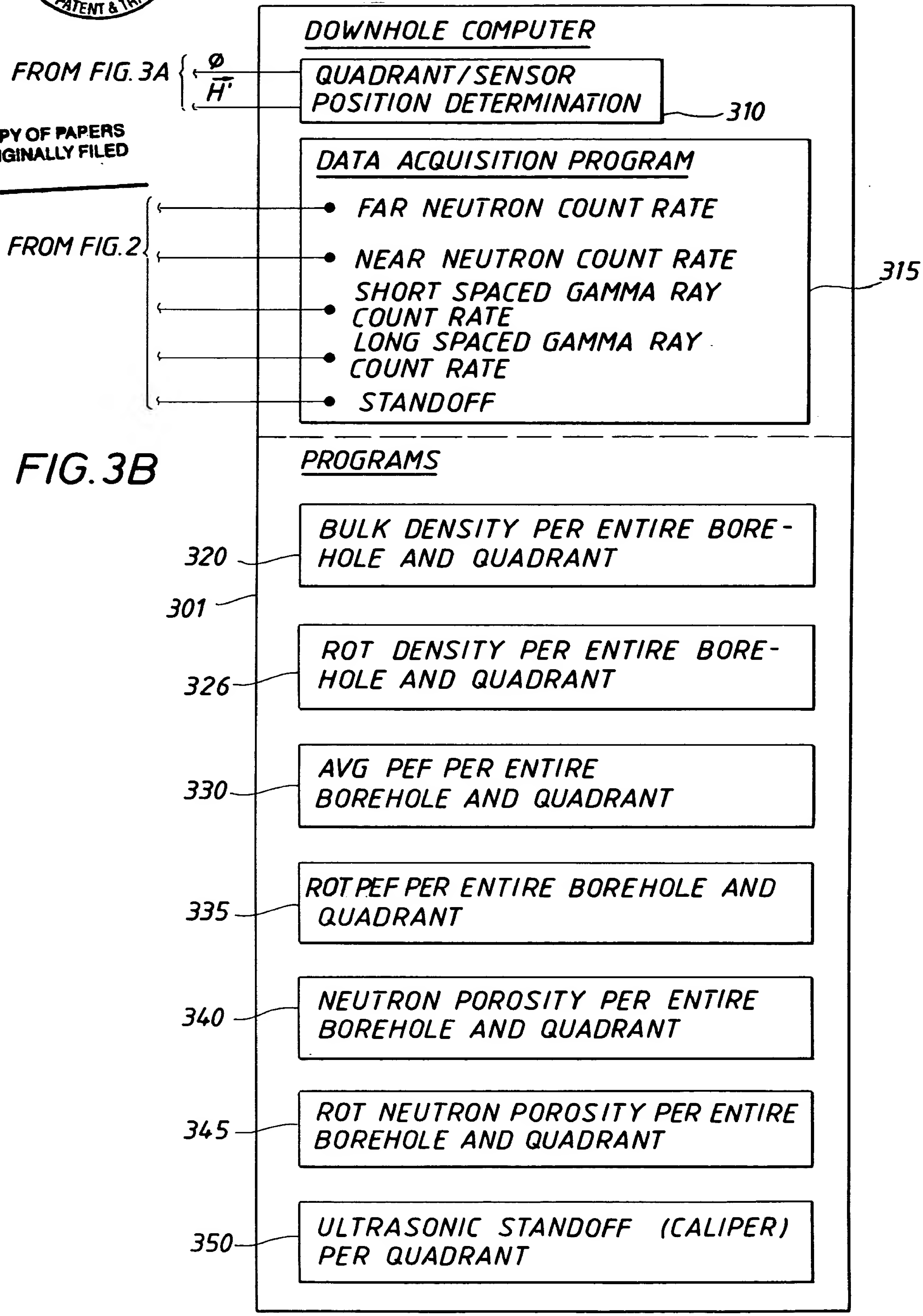

DOWNHOLE COMPUTER
FROM FIG. 3A
Ø
H'
QUADRANT/SENSOR POSITION DETERMINATION
310
DATA ACQUISITION PROGRAM
FROM FIG. 2
• FAR NEUTRON COUNT RATE
• NEAR NEUTRON COUNT RATE
• SHORT SPACED GAMMA RAY COUNT RATE
• LONG SPACED GAMMA RAY COUNT RATE
• STANDOFF
315
PROGRAMS
320
BULK DENSITY PER ENTIRE BORE-HOLE AND QUADRANT
301
326
ROT DENSITY PER ENTIRE BORE-HOLE AND QUADRANT
330
AVG PEF PER ENTIRE BOREHOLE AND QUADRANT
335
ROT PEF PER ENTIRE BOREHOLE AND QUADRANT
340
NEUTRON POROSITY PER ENTIRE BOREHOLE AND QUADRANT
345
ROT NEUTRON POROSITY PER ENTIRE BOREHOLE AND QUADRANT
350
ULTRASONIC STANDOFF (CALIPER) PER QUADRANT

FIG. 3B

FIG. 4A

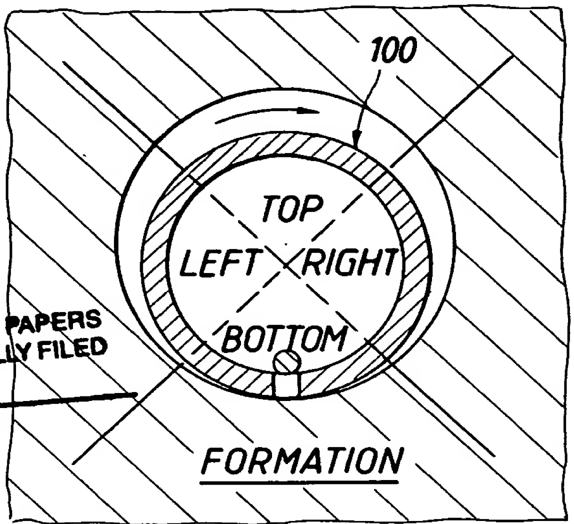
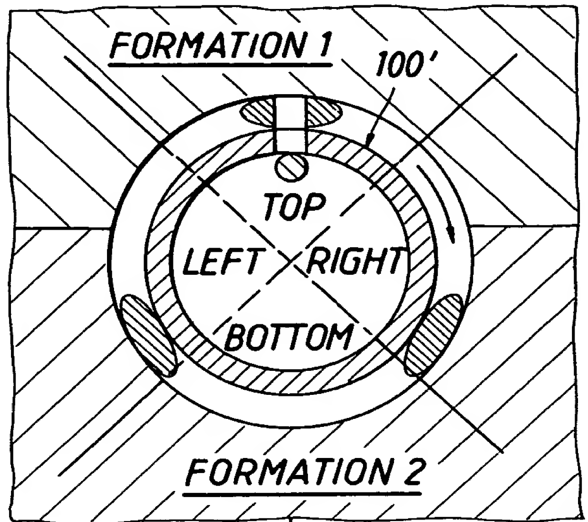



FIG. 4B



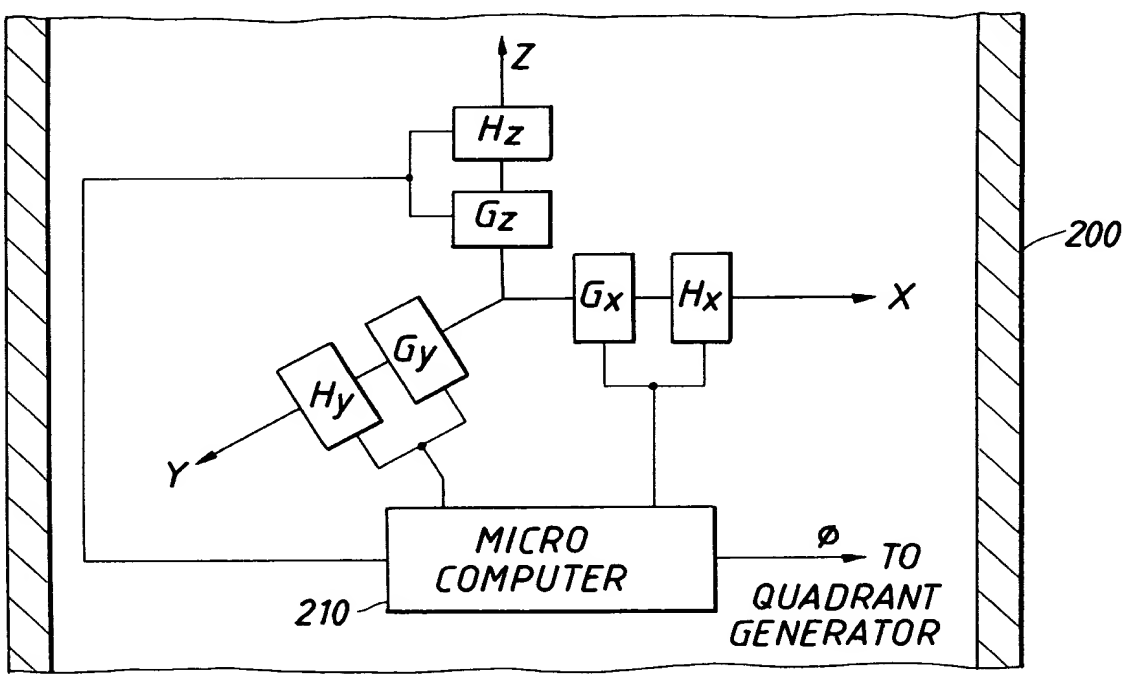




FIG. 5A

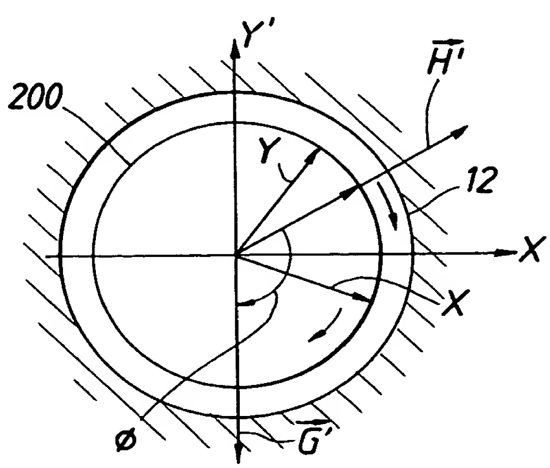
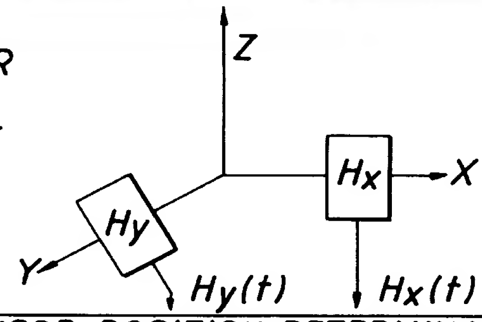



FIG. 5B

FIG. 6A

300

MAGNETOMETER SECTION




302

QUADRANT/SENSOR POSITION DETERMINATION COMPUTER PROGRAM

DETERMINE DOWN DIRECTION

- DETERMINE $\vec{H}'(t)$ VECTOR FROM $H_x(t)$, $H_y(t)$, $\measuredangle\theta(t)$
- DETERMINE DOWN DIRECTION ANGLE

$$\theta = \cos^{-1} \frac{H_x(t)}{(H_x^2 + H_y^2)^{1/2}}$$

Ø → $\measuredangle\vec{H}'(t) = \theta(t)$ AS MEASURED FROM TOOL X-AXIS

$\measuredangle\vec{D}(t) = \theta(t) - \varnothing$ AS MEASURED FROM TOOL X-AXIS

- DETERMINE BOTTOM QUADRANT

$Q_{BOT}(t) = \measuredangle\vec{D}(t) - 45°$ TO $\measuredangle\vec{D}(t) + 45°$

$Q_{LEFT}(t) = \measuredangle\vec{D}(t) + 45°$ TO $\measuredangle\vec{D}(t) + 135°$ 310

$Q_{TOP}(t) = \measuredangle\vec{D}(t) + 135°$ TO $\measuredangle\vec{D}(t) + 225°$

$Q_{RIGHT}(t) = \measuredangle\vec{D}(t) + 225°$ TO $\measuredangle\vec{D}(t) - 45°$

- DETERMINE QUADRANT OF SENSOR

$\measuredangle\vec{S}(t)$ IS MEASURED FROM X-AXIS AND $\vec{H}'(t)$ VECTOR

$\measuredangle\vec{S}$ IS $\propto$ DEGREES FROM X-AXIS

$\measuredangle\vec{H}'(t)$ IS $\theta(t)$ DEGREES FROM X-AXIS

$\measuredangle\vec{S}(t) = \propto$ AS MEASURED FROM X-AXIS IS

IN $Q_{BOT}$ WHEN $\measuredangle\vec{S}(t) = \propto$ IS BETWEEN $\theta(t) - \varnothing - 45°$ AND $\theta(t) - \varnothing + 45°$, ETC.

FIG.6B

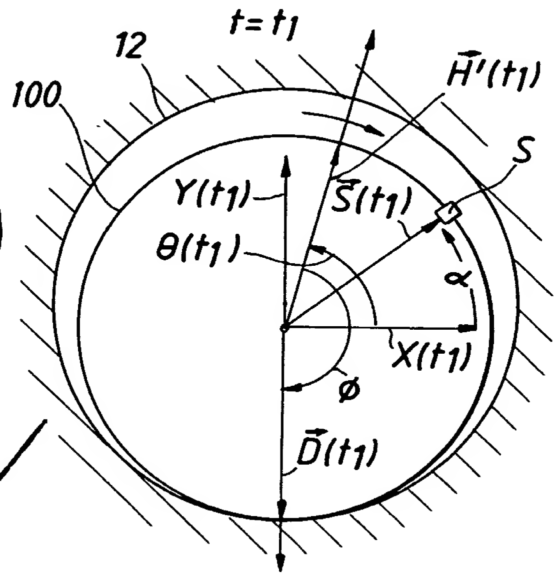
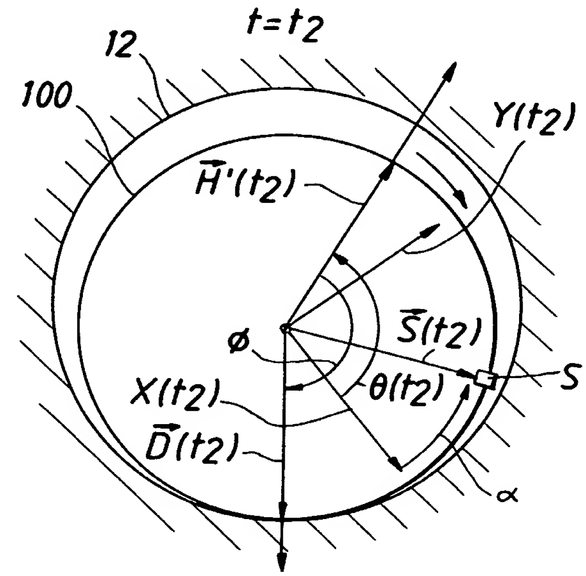



FIG.6C



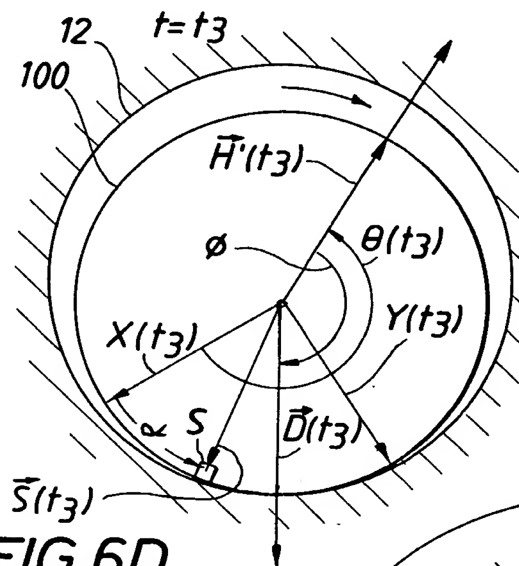




FIG.6D

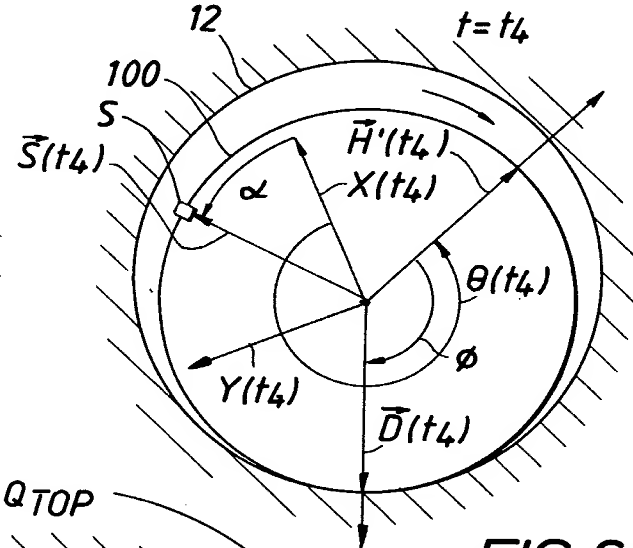



FIG.6E

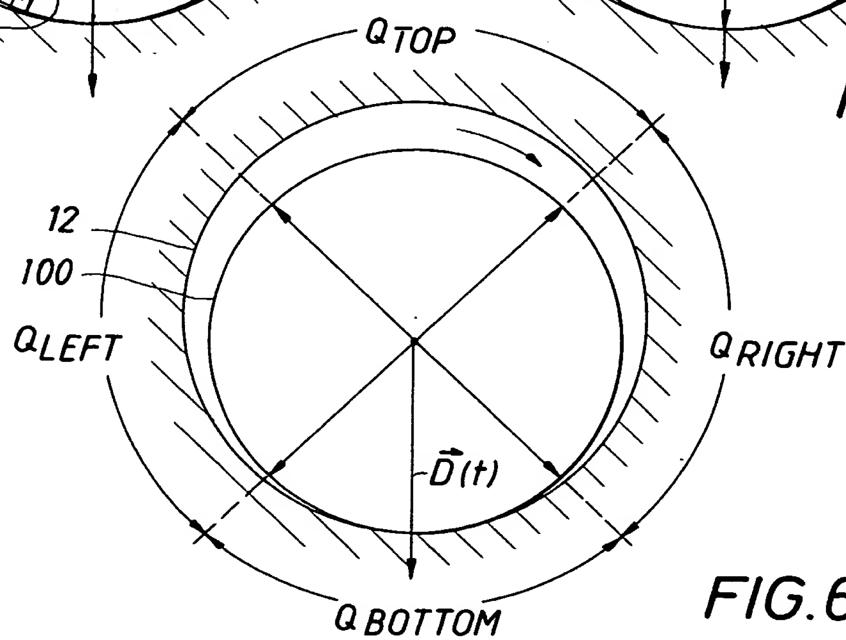



FIG.6F

FIG. 7A

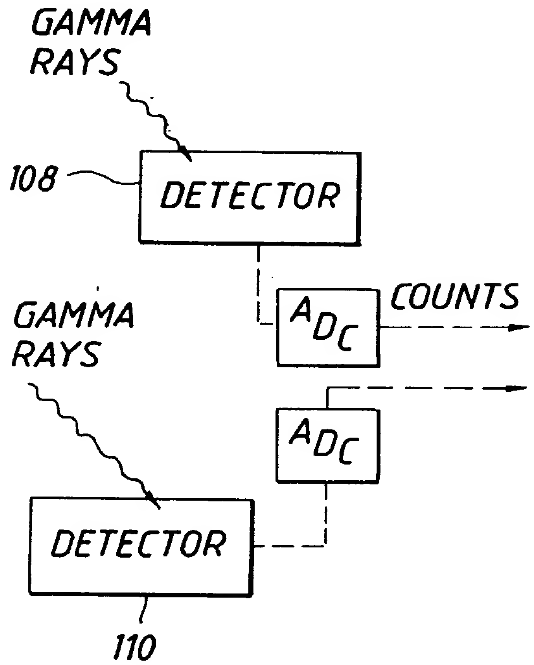
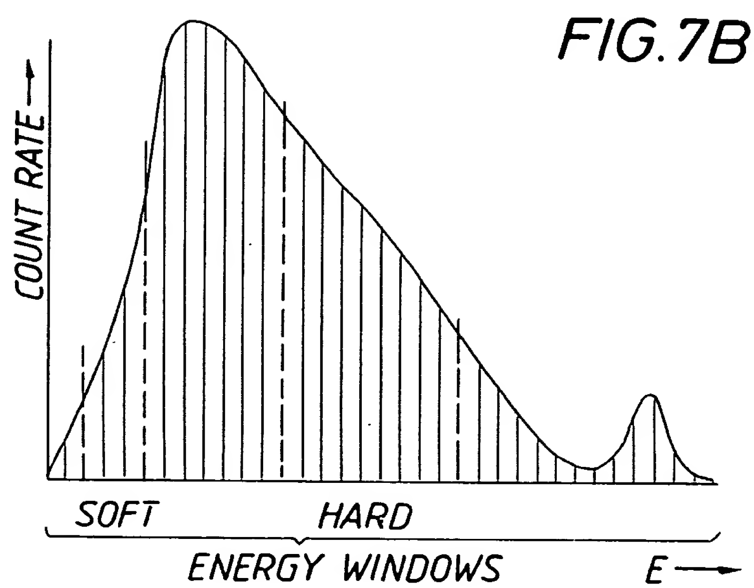

GAMMA RAYS
108
DETECTOR
ADC
COUNTS
GAMMA RAYS
ADC
DETECTOR
110

FIG. 7B


COUNT RATE
SOFT
HARD
ENERGY WINDOWS
E

Application Serial No.: 09/960,445
Docket No.: 19.0302
Title: Method of Kick Detection and Cuttings Bed Buildup Detection using a Drilling Tool
Inventors: Gzara et al.


FIG.8

315



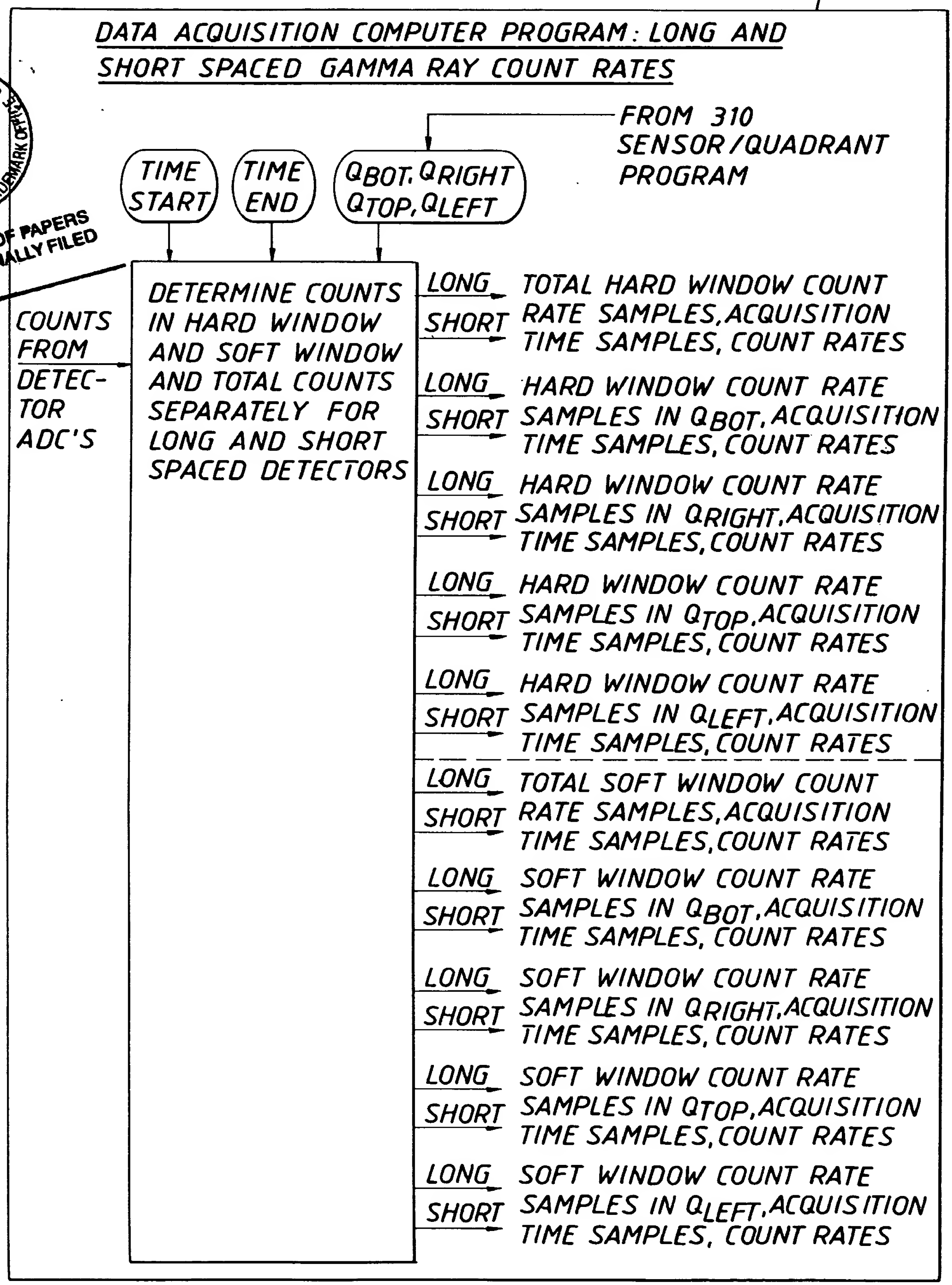


FIG. 9

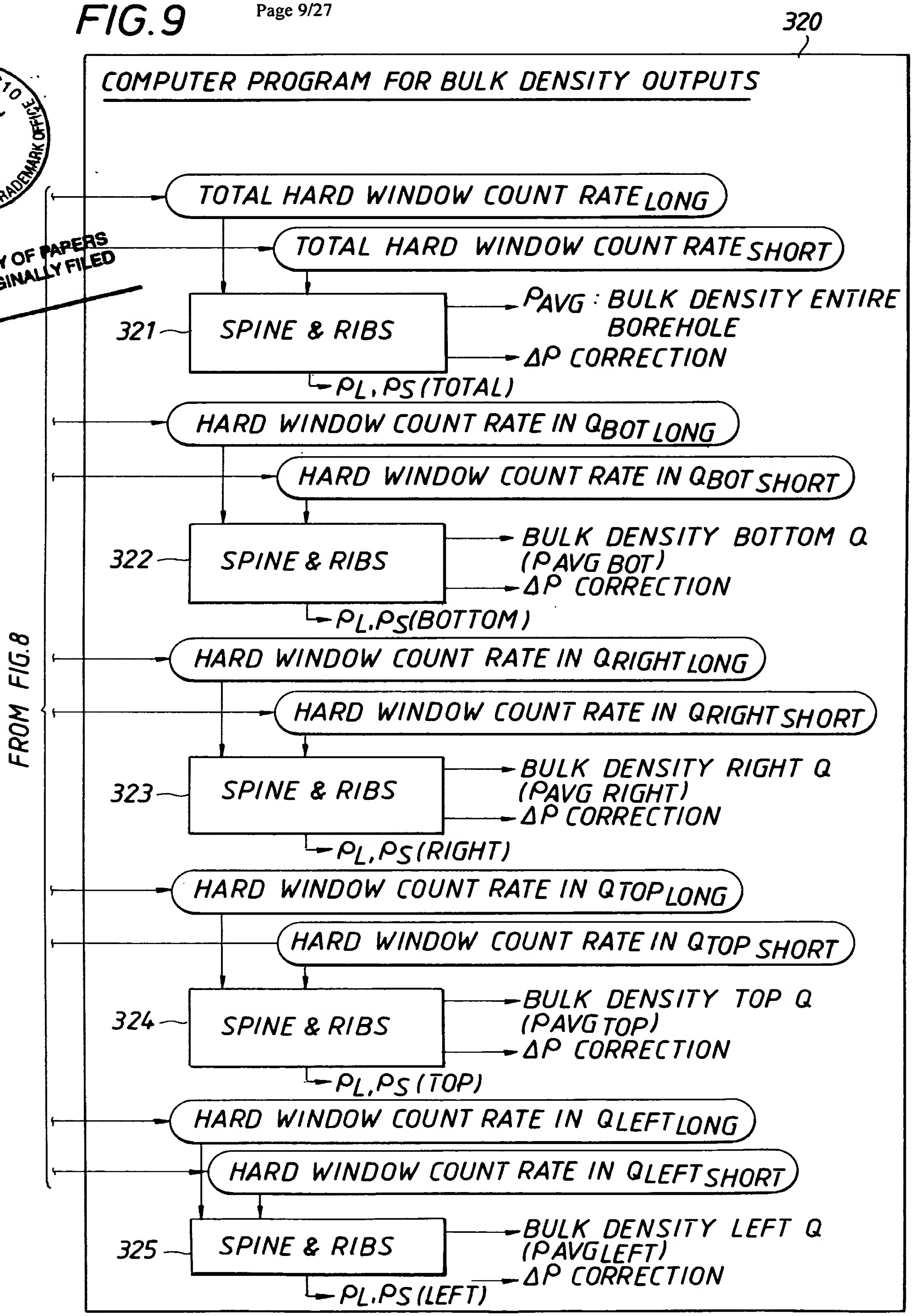
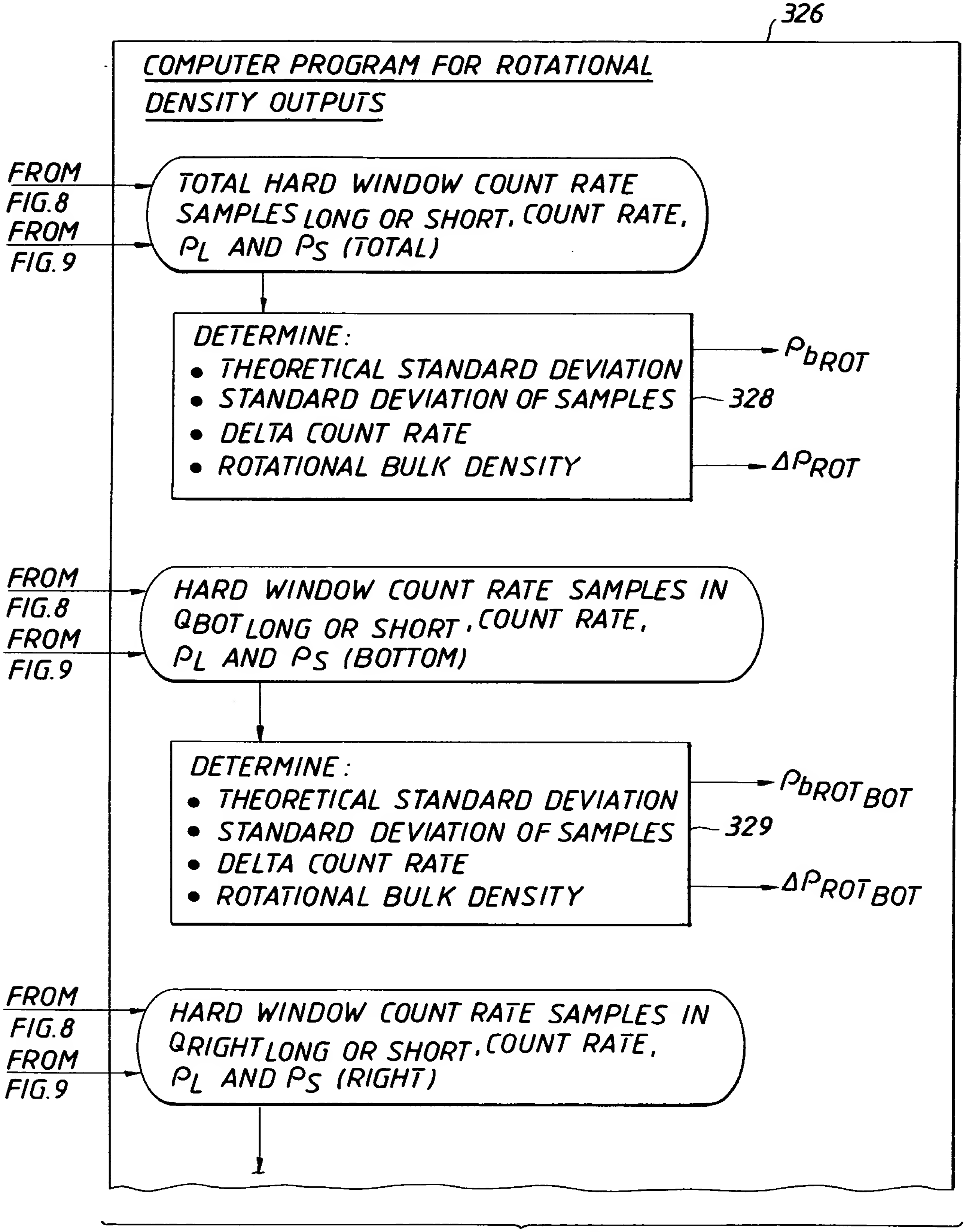
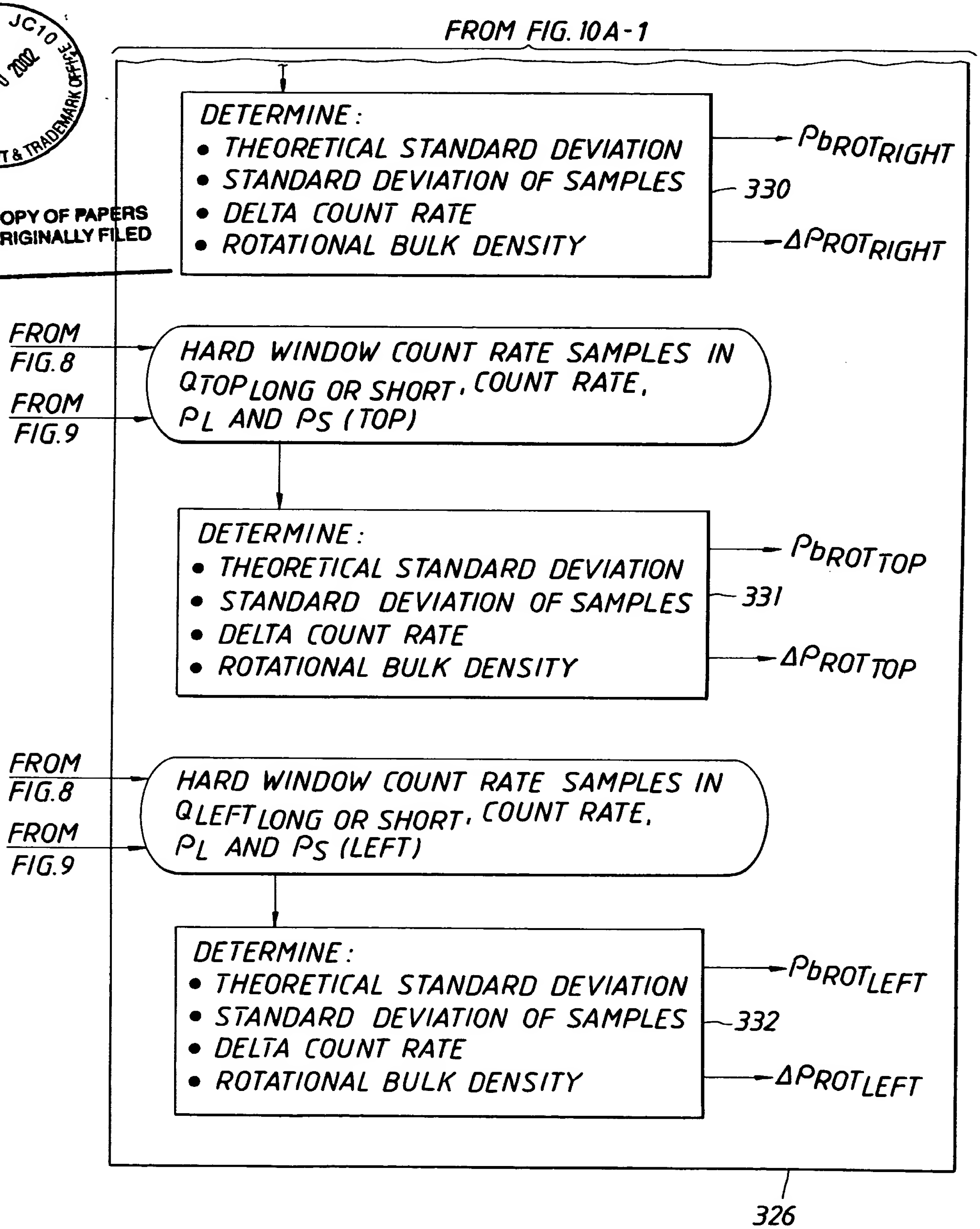

320
COMPUTER PROGRAM FOR BULK DENSITY OUTPUTS
FROM FIG.8
TOTAL HARD WINDOW COUNT RATE LONG
TOTAL HARD WINDOW COUNT RATE SHORT
321
SPINE & RIBS
ρAVG : BULK DENSITY ENTIRE BOREHOLE
Δρ CORRECTION
ρL, ρS (TOTAL)
HARD WINDOW COUNT RATE IN QBOT LONG
HARD WINDOW COUNT RATE IN QBOT SHORT
322
SPINE & RIBS
BULK DENSITY BOTTOM Q (ρAVG BOT)
Δρ CORRECTION
ρL, ρS (BOTTOM)
HARD WINDOW COUNT RATE IN QRIGHT LONG
HARD WINDOW COUNT RATE IN QRIGHT SHORT
323
SPINE & RIBS
BULK DENSITY RIGHT Q (ρAVG RIGHT)
Δρ CORRECTION
ρL, ρS (RIGHT)
HARD WINDOW COUNT RATE IN QTOP LONG
HARD WINDOW COUNT RATE IN QTOP SHORT
324
SPINE & RIBS
BULK DENSITY TOP Q (ρAVG TOP)
Δρ CORRECTION
ρL, ρS (TOP)
HARD WINDOW COUNT RATE IN QLEFT LONG
HARD WINDOW COUNT RATE IN QLEFT SHORT
325
SPINE & RIBS
BULK DENSITY LEFT Q (ρAVG LEFT)
Δρ CORRECTION
ρL, ρS (LEFT)

FIG. 10A-1




TO FIG. 10A-2

FIG. 10A-2


FROM FIG. 10A-1
DETERMINE:
• THEORETICAL STANDARD DEVIATION
• STANDARD DEVIATION OF SAMPLES
• DELTA COUNT RATE
• ROTATIONAL BULK DENSITY
ρbROTRIGHT
330
ΔρROTRIGHT
FROM FIG. 8
FROM FIG. 9
HARD WINDOW COUNT RATE SAMPLES IN QTOP LONG OR SHORT, COUNT RATE, ρL AND ρS (TOP)
DETERMINE:
• THEORETICAL STANDARD DEVIATION
• STANDARD DEVIATION OF SAMPLES
• DELTA COUNT RATE
• ROTATIONAL BULK DENSITY
ρbROTTOP
331
ΔρROTTOP
FROM FIG. 8
FROM FIG. 9
HARD WINDOW COUNT RATE SAMPLES IN QLEFT LONG OR SHORT, COUNT RATE, ρL AND ρS (LEFT)
DETERMINE:
• THEORETICAL STANDARD DEVIATION
• STANDARD DEVIATION OF SAMPLES
• DELTA COUNT RATE
• ROTATIONAL BULK DENSITY
ρbROTLEFT
332
ΔρROTLEFT
326

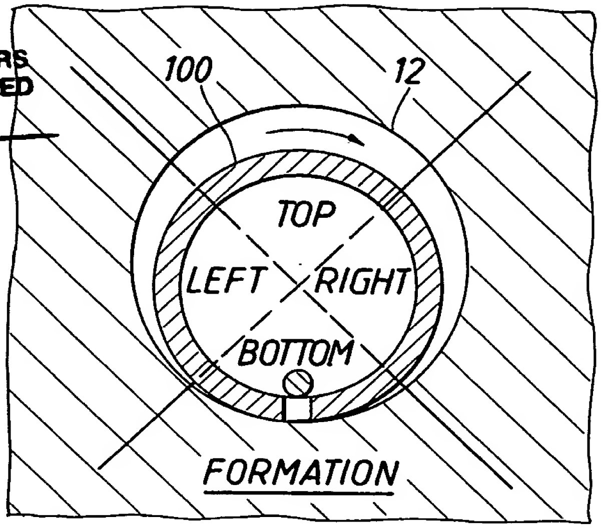



FIG.10B

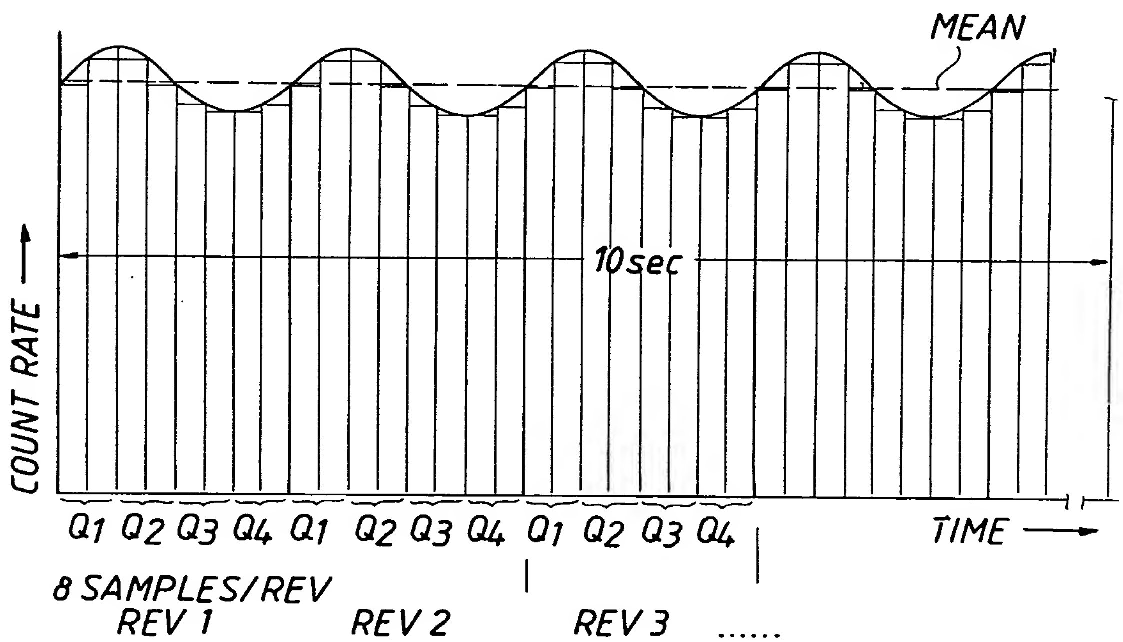
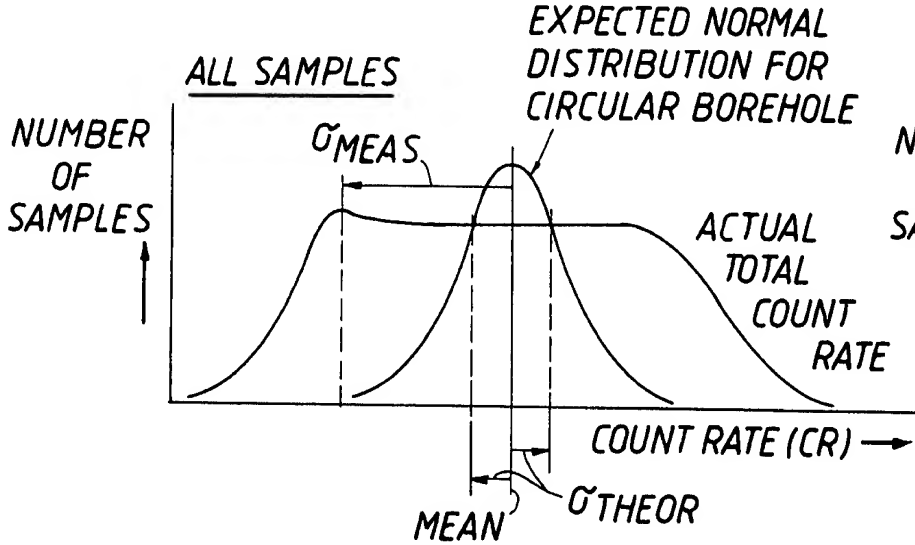



FIG.10C




$$\Delta CR = A\sqrt{\sigma^2 MEAS - \sigma^2 THEOR}$$

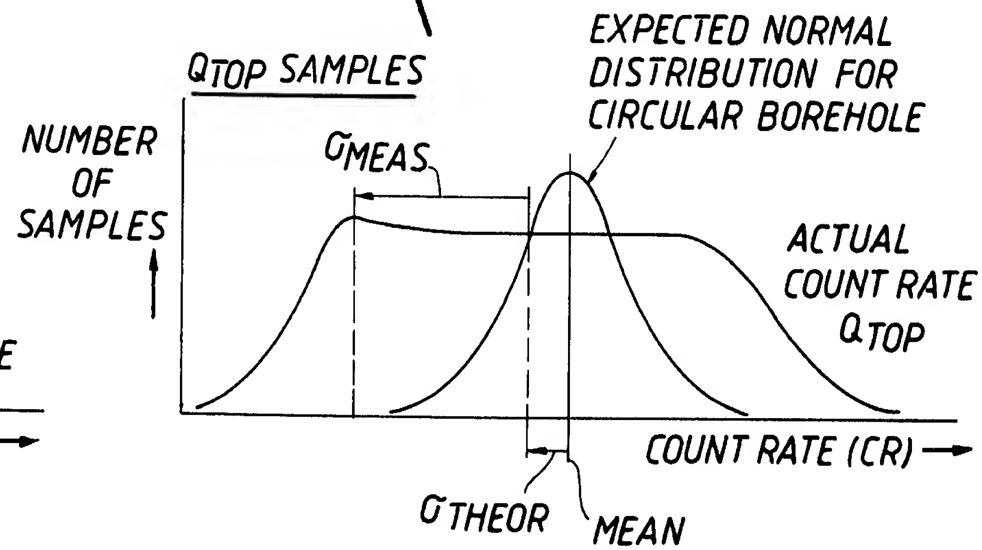
$$\Delta\rho_{ROT} = (ds)\left[\ln\left(\frac{CR+\Delta CR}{CR-\Delta CR}\right)\right]$$

$$\rho_{bROT} = D\rho_L + E\rho_S + F\Delta\rho_{ROT}$$

$\rho_L$ = LONG SPACING DENSITY

$\rho_S$ = SHORT SPACING DENSITY

FIG. 10D-1




$$\Delta CR_{TOP} = A\sqrt{\sigma^2 MEAS_{TOP} - \sigma^2 THEOR_{TOP}}$$

$$\Delta\rho_{ROT\,TOP} = (ds)\left[\ln\left(\frac{CR_{TOP} + \Delta CR_{TOP}}{CR_{TOP} - \Delta CR_{TOP}}\right)\right]$$

$$\rho_{bROT\,TOP} = D\rho_{L\,TOP} + E\rho_{S\,TOP} + F\Delta\rho_{ROT\,TOP}$$

$\rho_{L\,TOP}$ = LONG SPACING DENSITY TOP

$\rho_{S\,TOP}$ = SHORT SPACING DENSITY TOP

FIG. 10D-2

# FIG.11A



330

COMPUTER PROGRAM FOR AVERAGE PHOTOELECTRIC EFFECT (PEF) OUTPUTS

FROM FIG.8 → TOTAL SOFT WINDOW COUNT RATE SHORT OR LONG; TOTAL HARD WINDOW COUNT RATE SHORT OR LONG

FROM FIG.9 → $P_{AVG}$

- DETERMINE MACROSCOPIC CROSS-SECTION $U_{AVG}$

$$U_{AVG} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$$

- DETERMINE $PEF_{AVG}$

$$PEF_{AVG} = \frac{U_{AVG}}{P_{AVG}}$$

→ $PEF_{AVG}$

FROM FIG.8 → SOFT WINDOW COUNT RATE IN $Q_{BOT}$ SHORT OR LONG; HARD WINDOW COUNT RATE IN $Q_{BOT}$ SHORT OR LONG

FROM FIG.9 → $P_{AVG\,BOT}$

- DETERMINE MACROSCOPIC CROSS-SECTION $U_{AVG\,BOT}$

$$U_{AVG\,BOT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE } Q_{BOT}}{\text{HARD COUNT RATE } Q_{BOT}}\right) - B}\right] - C$$

- DETERMINE $PEF_{AVG\,BOT}$

$$PEF_{AVG\,BOT} = \frac{U_{AVG\,BOT}}{P_{AVG\,BOT}}$$

→ $PEF_{AVG\,BOT}$

FROM FIG. 8 → SOFT WINDOW COUNT RATE IN $Q_{RIGHT}$ SHORT OR LONG; HARD WINDOW COUNT RATE IN $Q_{RIGHT}$ SHORT OR LONG

TO FIG. 11B

FIG. 11B

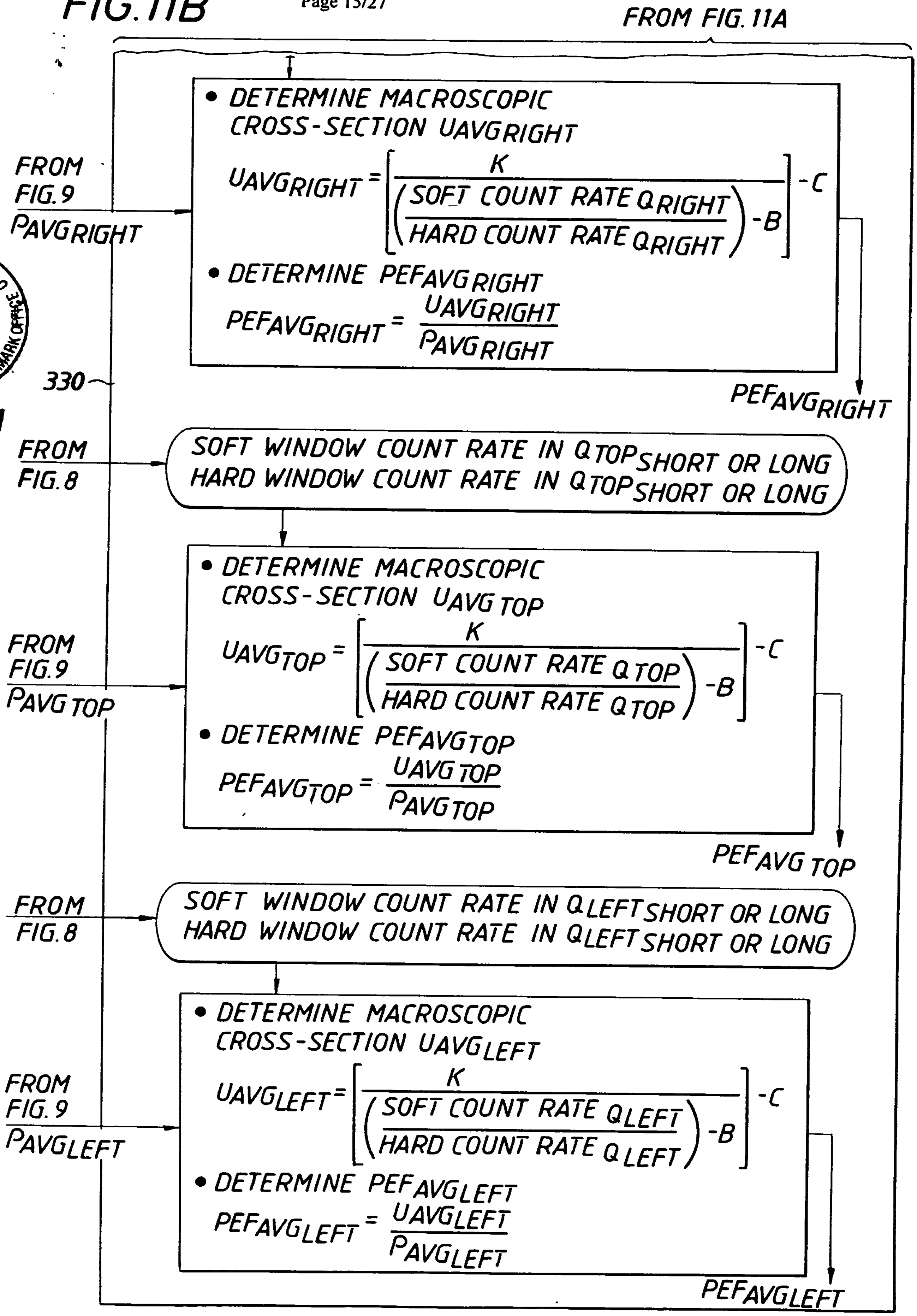

FROM FIG. 11A
FROM FIG. 9 PAVGRIGHT
• DETERMINE MACROSCOPIC CROSS-SECTION UAVGRIGHT
UAVGRIGHT = [K / ((SOFT COUNT RATE QRIGHT / HARD COUNT RATE QRIGHT) - B)] - C
• DETERMINE PEFAVGRIGHT
PEFAVGRIGHT = UAVGRIGHT / PAVGRIGHT
PEFAVGRIGHT
330
FROM FIG. 8
SOFT WINDOW COUNT RATE IN QTOPSHORT OR LONG
HARD WINDOW COUNT RATE IN QTOPSHORT OR LONG
FROM FIG. 9 PAVGTOP
• DETERMINE MACROSCOPIC CROSS-SECTION UAVGTOP
UAVGTOP = [K / ((SOFT COUNT RATE QTOP / HARD COUNT RATE QTOP) - B)] - C
• DETERMINE PEFAVGTOP
PEFAVGTOP = UAVGTOP / PAVGTOP
PEFAVGTOP
FROM FIG. 8
SOFT WINDOW COUNT RATE IN QLEFTSHORT OR LONG
HARD WINDOW COUNT RATE IN QLEFTSHORT OR LONG
FROM FIG. 9 PAVGLEFT
• DETERMINE MACROSCOPIC CROSS-SECTION UAVGLEFT
UAVGLEFT = [K / ((SOFT COUNT RATE QLEFT / HARD COUNT RATE QLEFT) - B)] - C
• DETERMINE PEFAVGLEFT
PEFAVGLEFT = UAVGLEFT / PAVGLEFT
PEFAVGLEFT

FIG. 12A

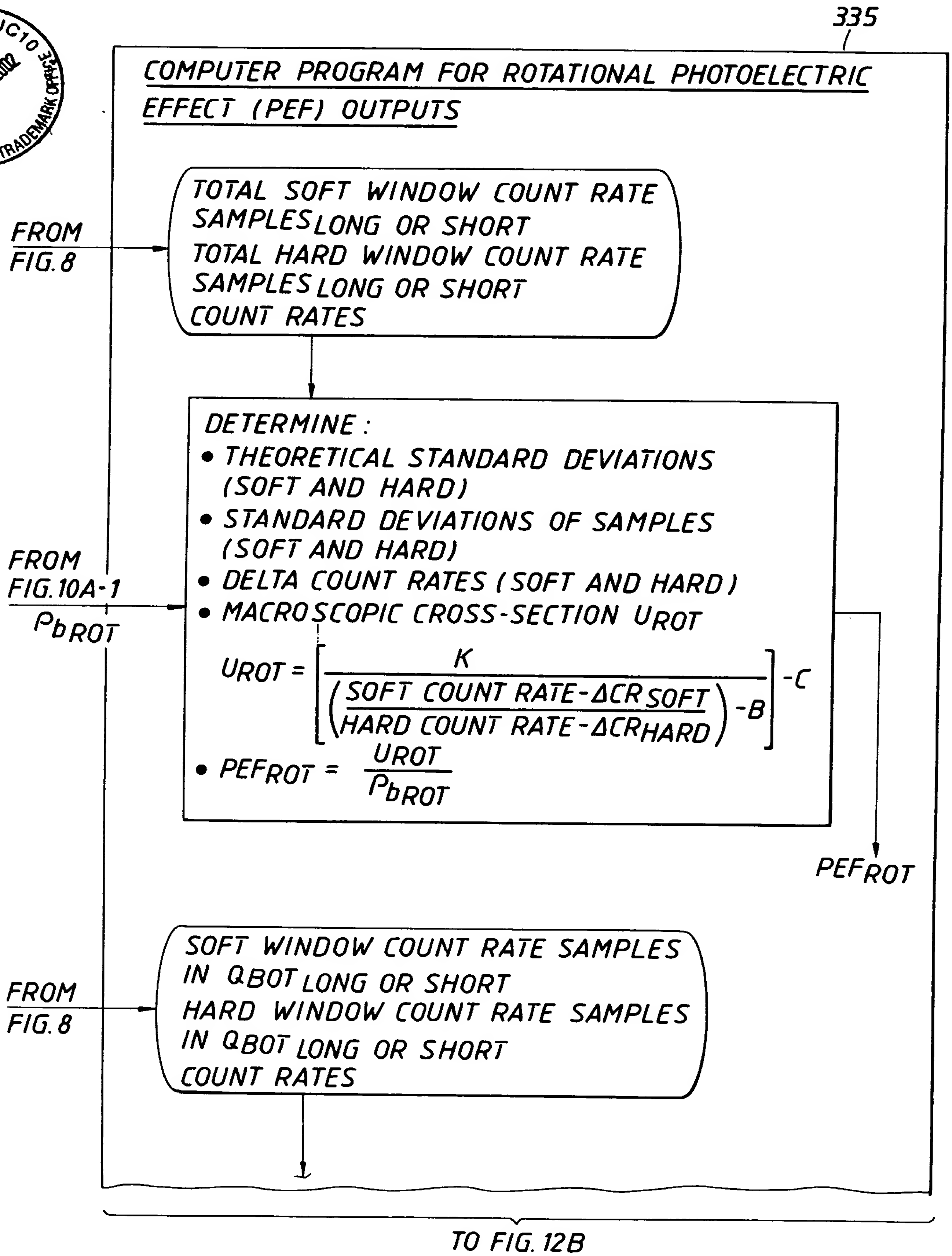

335
COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC EFFECT (PEF) OUTPUTS
FROM FIG. 8
TOTAL SOFT WINDOW COUNT RATE SAMPLES LONG OR SHORT
TOTAL HARD WINDOW COUNT RATE SAMPLES LONG OR SHORT
COUNT RATES
FROM FIG. 10A-1
ρb ROT
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT AND HARD)
• MACROSCOPIC CROSS-SECTION UROT
$U_{ROT} = \left[ \dfrac{K}{\left( \dfrac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}} \right) - B} \right] - C$
• $PEF_{ROT} = \dfrac{U_{ROT}}{\rho_{b\,ROT}}$
$PEF_{ROT}$
FROM FIG. 8
SOFT WINDOW COUNT RATE SAMPLES IN QBOT LONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN QBOT LONG OR SHORT
COUNT RATES
TO FIG. 12B

FIG.12B

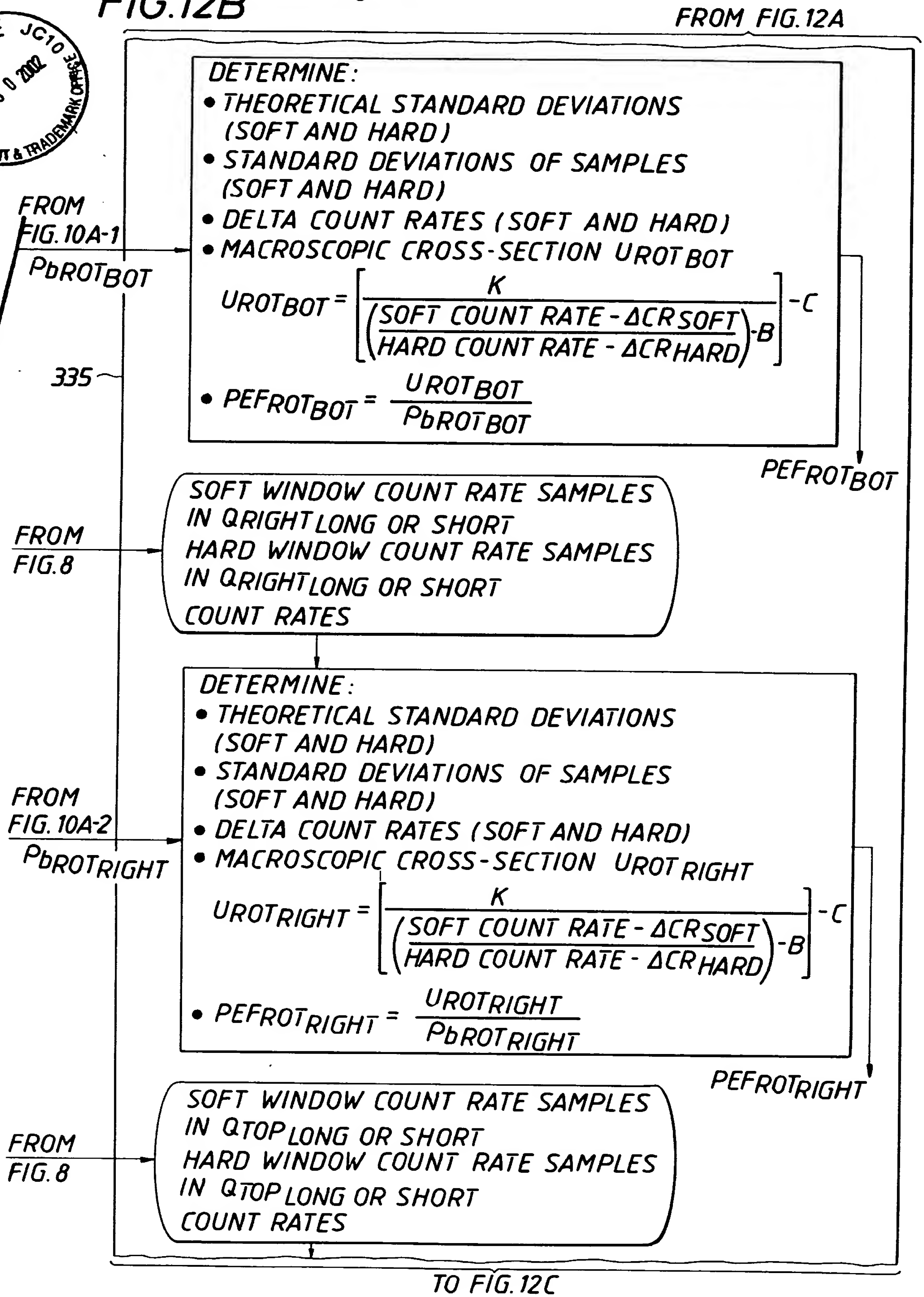

FROM FIG.12A
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT AND HARD)
• MACROSCOPIC CROSS-SECTION UROTBOT
$$U_{ROTBOT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}}\right) - B}\right] - C$$
• $PEF_{ROTBOT} = \frac{U_{ROTBOT}}{P_{bROTBOT}}$
FROM FIG.10A-1
PbROTBOT
335
PEFROTBOT
SOFT WINDOW COUNT RATE SAMPLES IN QRIGHT LONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN QRIGHT LONG OR SHORT
COUNT RATES
FROM FIG.8
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT AND HARD)
• MACROSCOPIC CROSS-SECTION UROTRIGHT
$$U_{ROTRIGHT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}}\right) - B}\right] - C$$
• $PEF_{ROTRIGHT} = \frac{U_{ROTRIGHT}}{P_{bROTRIGHT}}$
FROM FIG.10A-2
PbROTRIGHT
PEFROTRIGHT
SOFT WINDOW COUNT RATE SAMPLES IN QTOP LONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN QTOP LONG OR SHORT
COUNT RATES
FROM FIG.8
TO FIG.12C

FIG. 12C

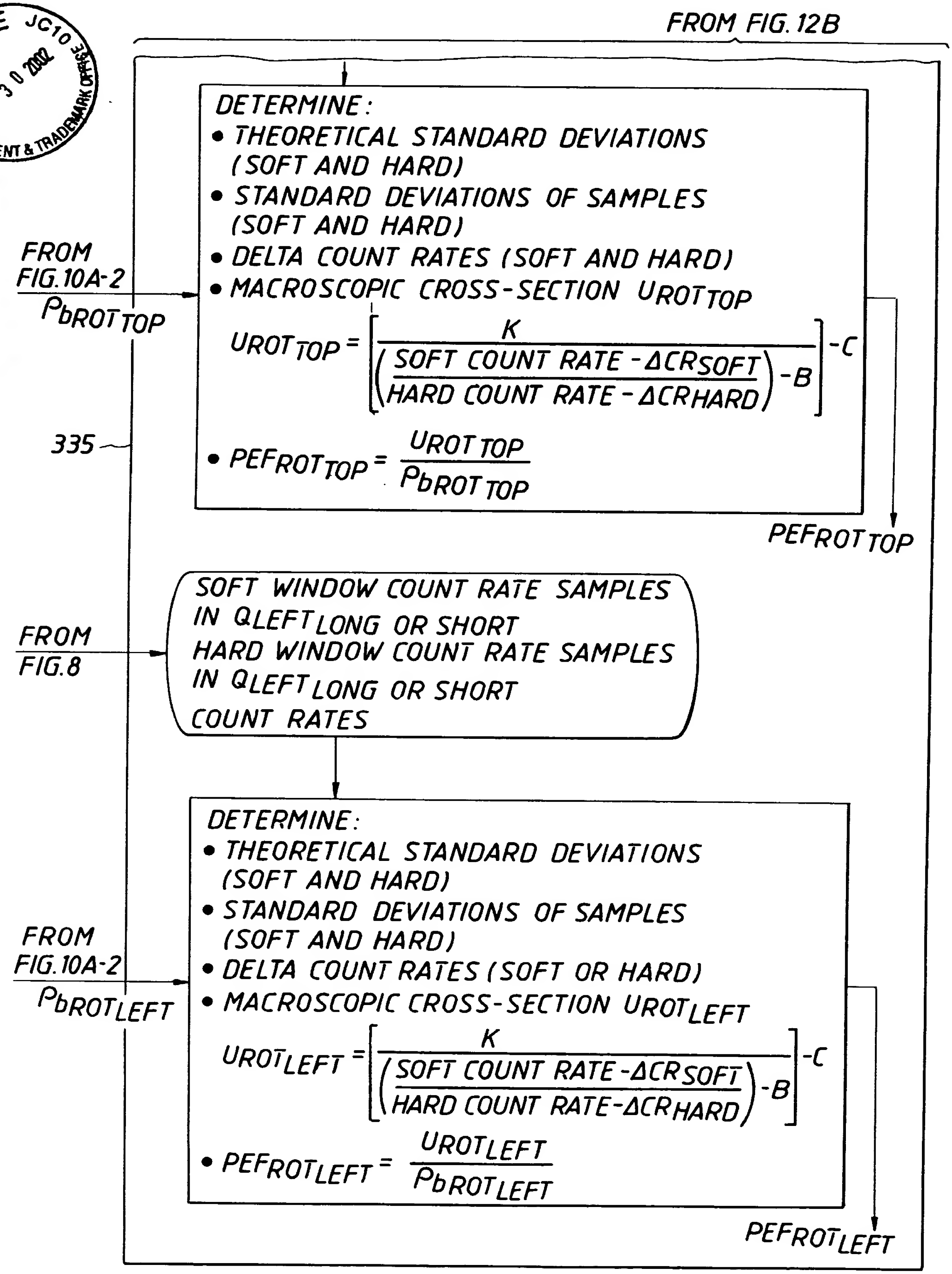
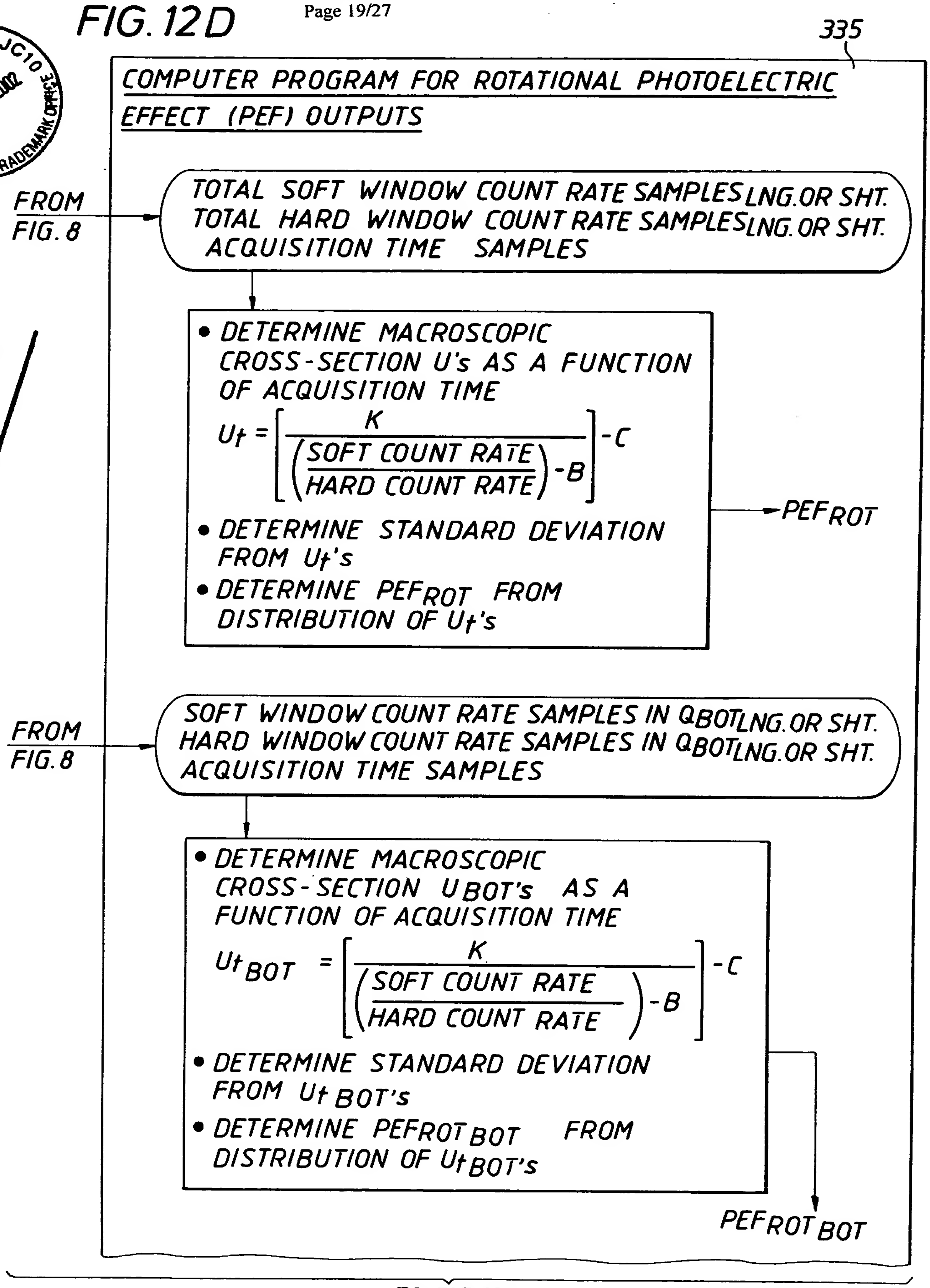

FROM FIG. 12B
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT AND HARD)
• MACROSCOPIC CROSS-SECTION $U_{ROT\,TOP}$
$U_{ROT\,TOP} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}}\right) - B}\right] - C$
• $PEF_{ROT\,TOP} = \frac{U_{ROT\,TOP}}{\rho_{b\,ROT\,TOP}}$
FROM FIG. 10A-2
$\rho_{b\,ROT\,TOP}$
335
$PEF_{ROT\,TOP}$
SOFT WINDOW COUNT RATE SAMPLES IN $Q_{LEFT}$ LONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN $Q_{LEFT}$ LONG OR SHORT
COUNT RATES
FROM FIG. 8
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT OR HARD)
• MACROSCOPIC CROSS-SECTION $U_{ROT\,LEFT}$
$U_{ROT\,LEFT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}}\right) - B}\right] - C$
• $PEF_{ROT\,LEFT} = \frac{U_{ROT\,LEFT}}{\rho_{b\,ROT\,LEFT}}$
FROM FIG. 10A-2
$\rho_{b\,ROT\,LEFT}$
$PEF_{ROT\,LEFT}$

FIG. 12D




TO FIG. 12E

FIG. 12E

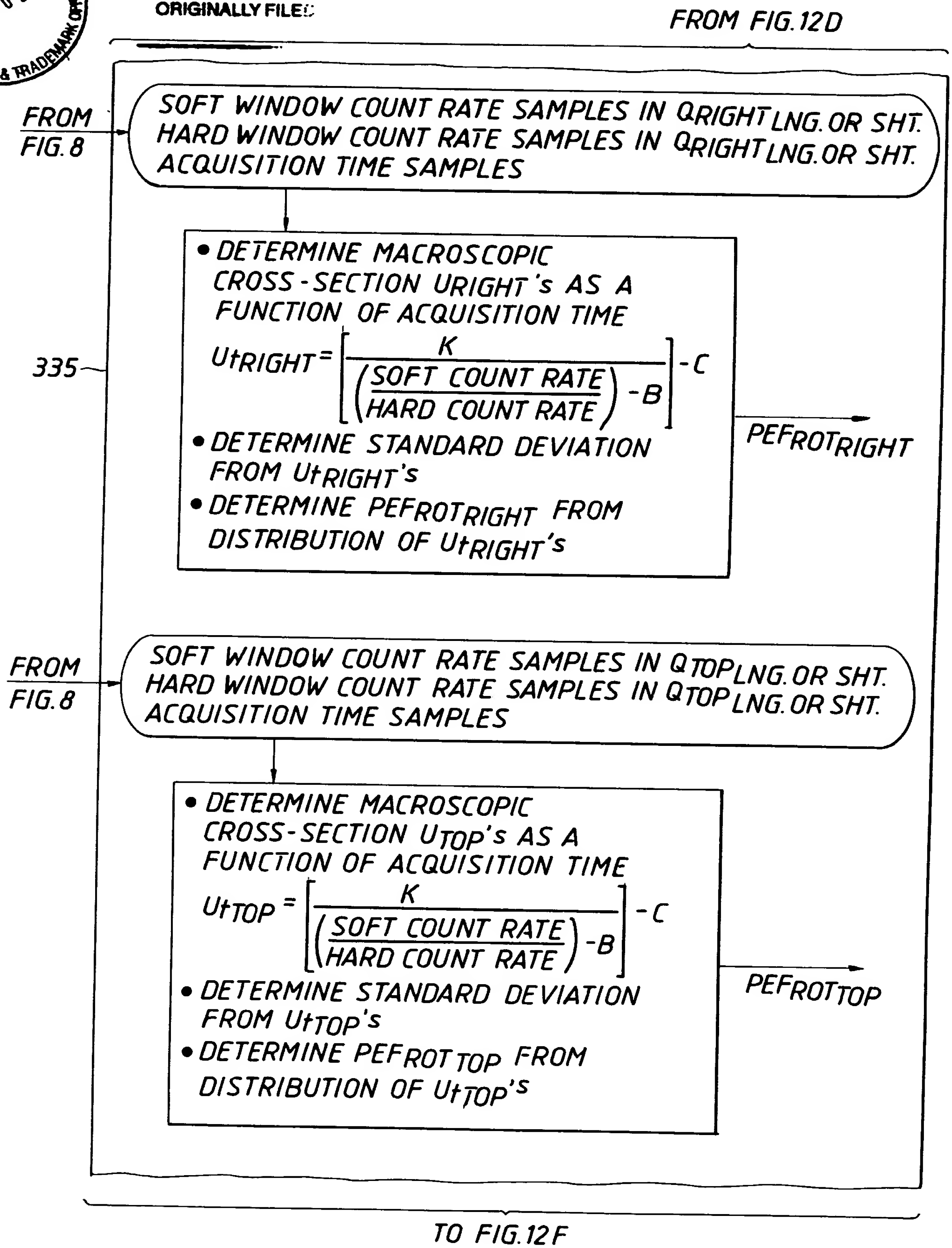

FROM FIG.12D
FROM FIG.8
SOFT WINDOW COUNT RATE SAMPLES IN QRIGHT LNG. OR SHT.
HARD WINDOW COUNT RATE SAMPLES IN QRIGHT LNG. OR SHT.
ACQUISITION TIME SAMPLES
335
• DETERMINE MACROSCOPIC CROSS-SECTION URIGHT's AS A FUNCTION OF ACQUISITION TIME
$U_{tRIGHT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right) - B} \right] - C$
• DETERMINE STANDARD DEVIATION FROM UtRIGHT's
• DETERMINE PEFROTRIGHT FROM DISTRIBUTION OF UtRIGHT's
PEFROTRIGHT
FROM FIG.8
SOFT WINDOW COUNT RATE SAMPLES IN QTOP LNG. OR SHT.
HARD WINDOW COUNT RATE SAMPLES IN QTOP LNG. OR SHT.
ACQUISITION TIME SAMPLES
• DETERMINE MACROSCOPIC CROSS-SECTION UTOP's AS A FUNCTION OF ACQUISITION TIME
$U_{tTOP} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right) - B} \right] - C$
• DETERMINE STANDARD DEVIATION FROM UtTOP's
• DETERMINE PEFROTTOP FROM DISTRIBUTION OF UtTOP's
PEFROTTOP
TO FIG.12F

FIG. 12F

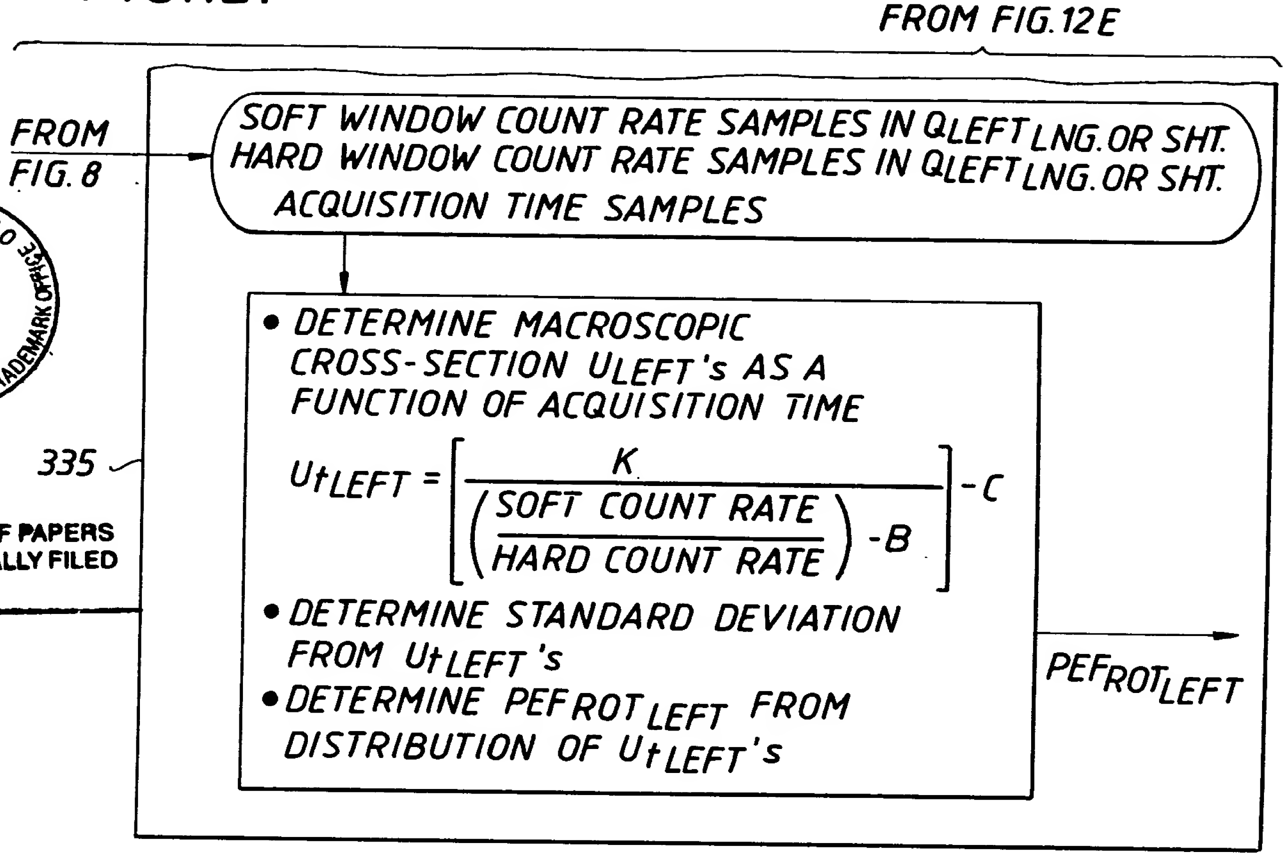





FIG. 13

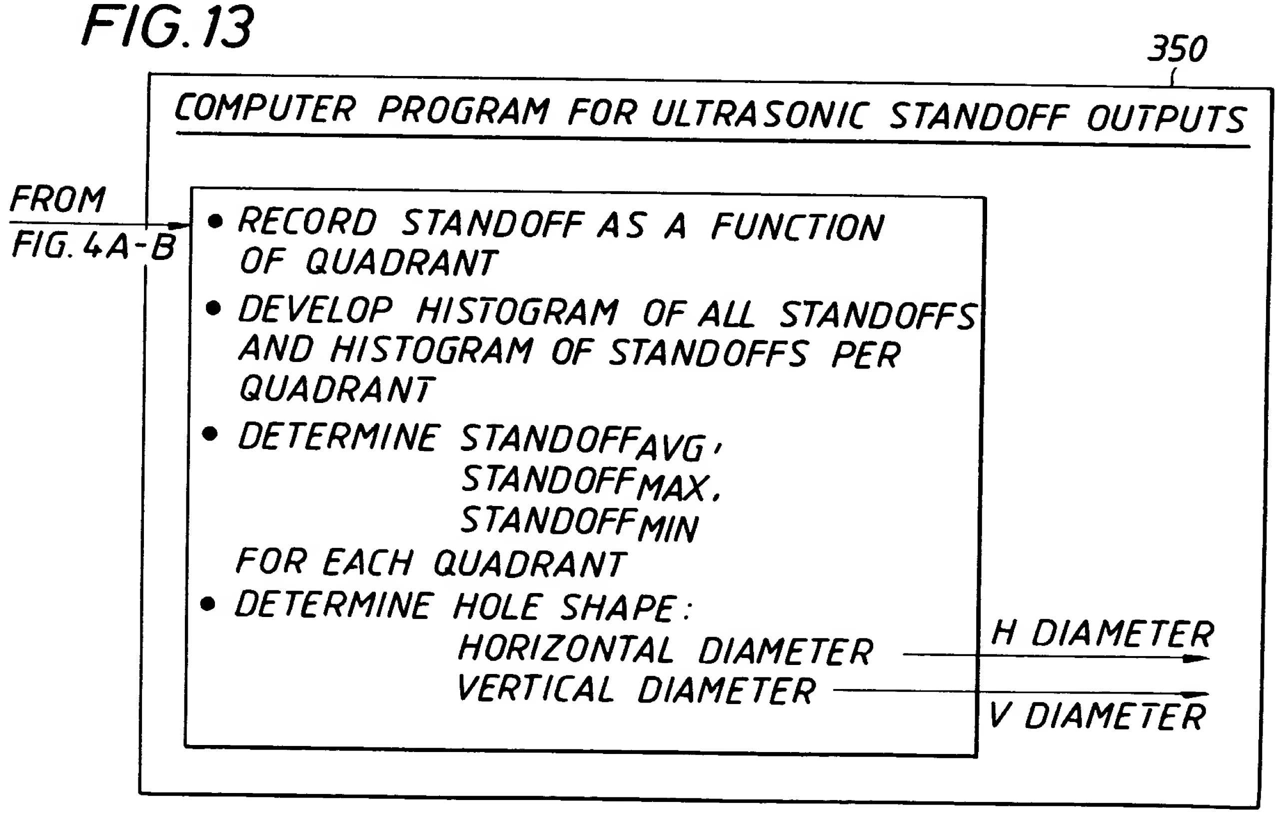
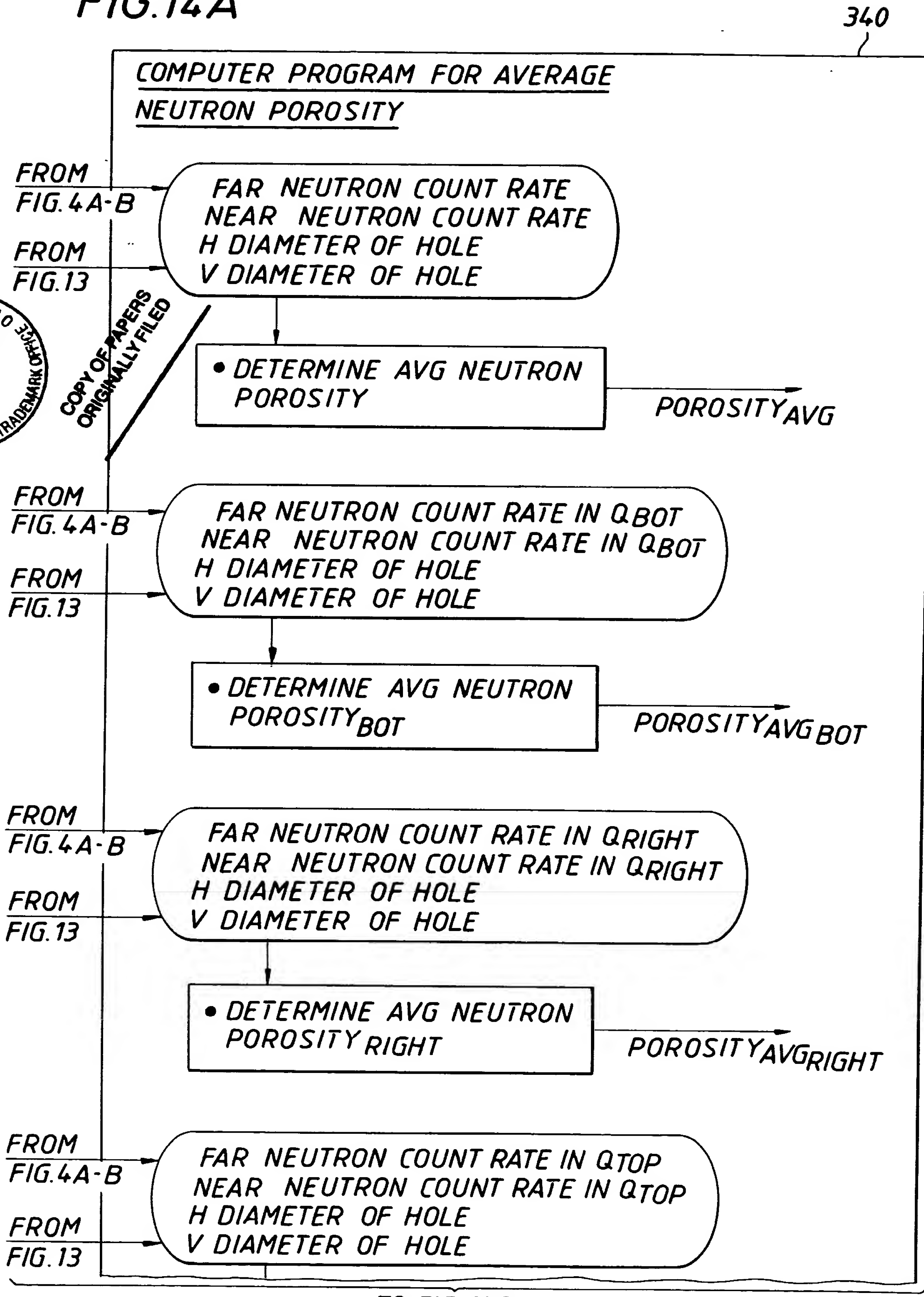


FIG.14A




TO FIG. 14B

FIG. 14B

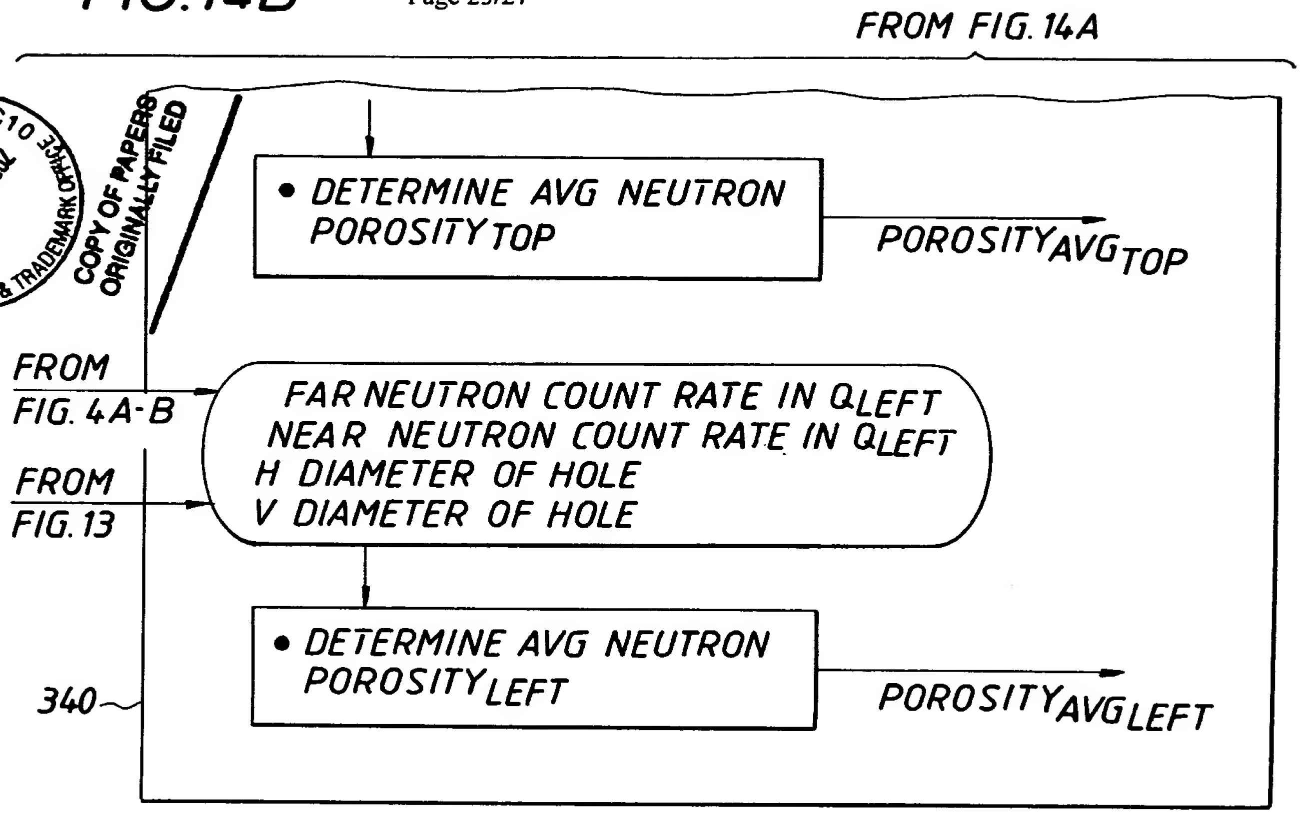





FIG. 15A

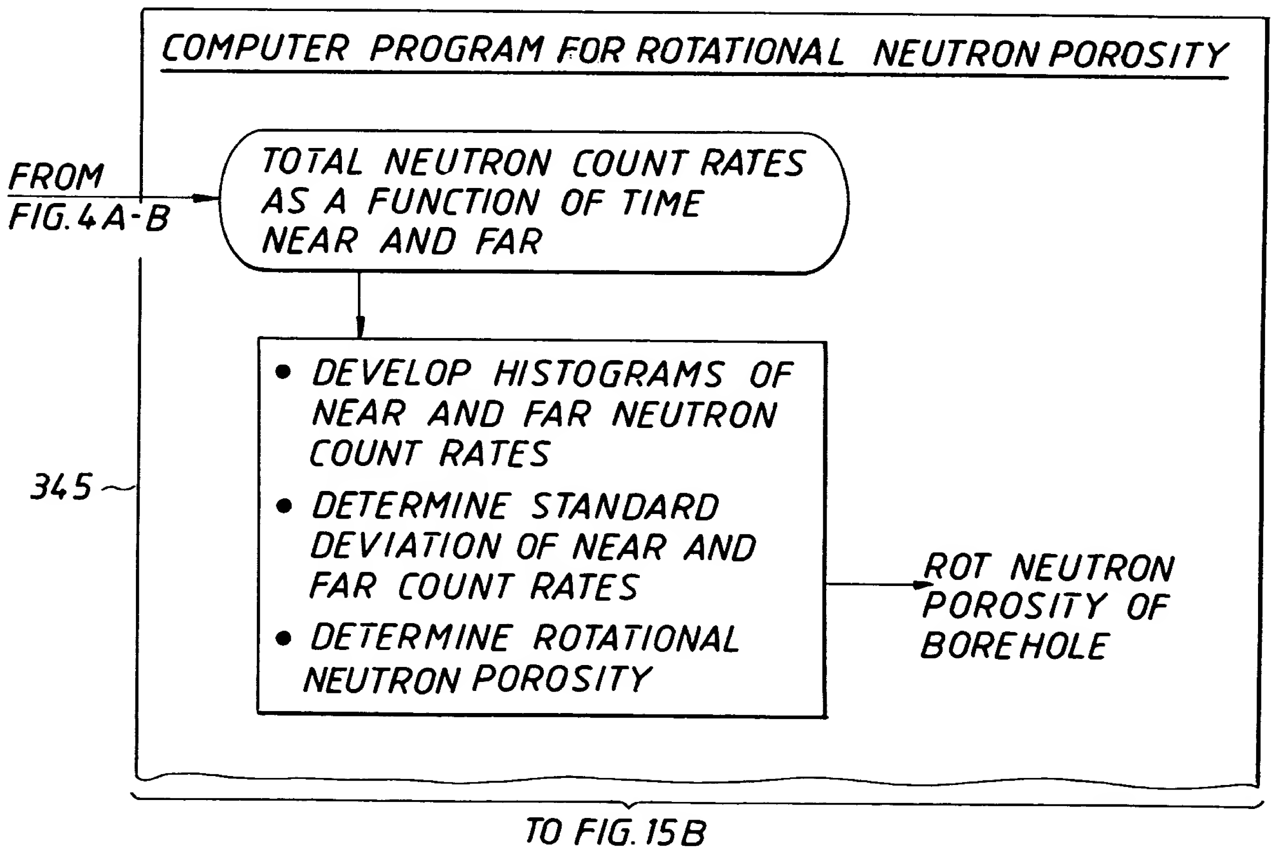


FIG.15B

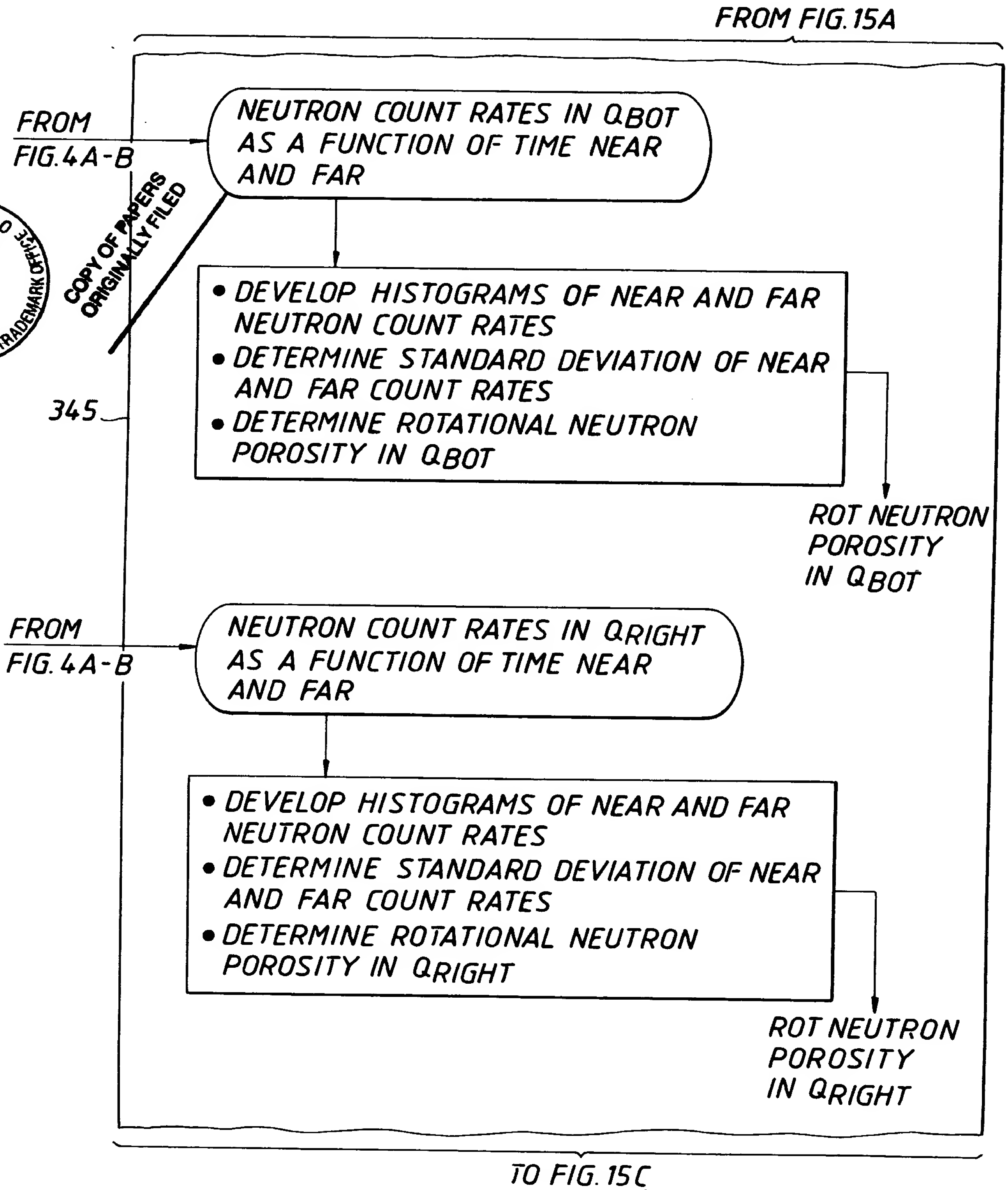
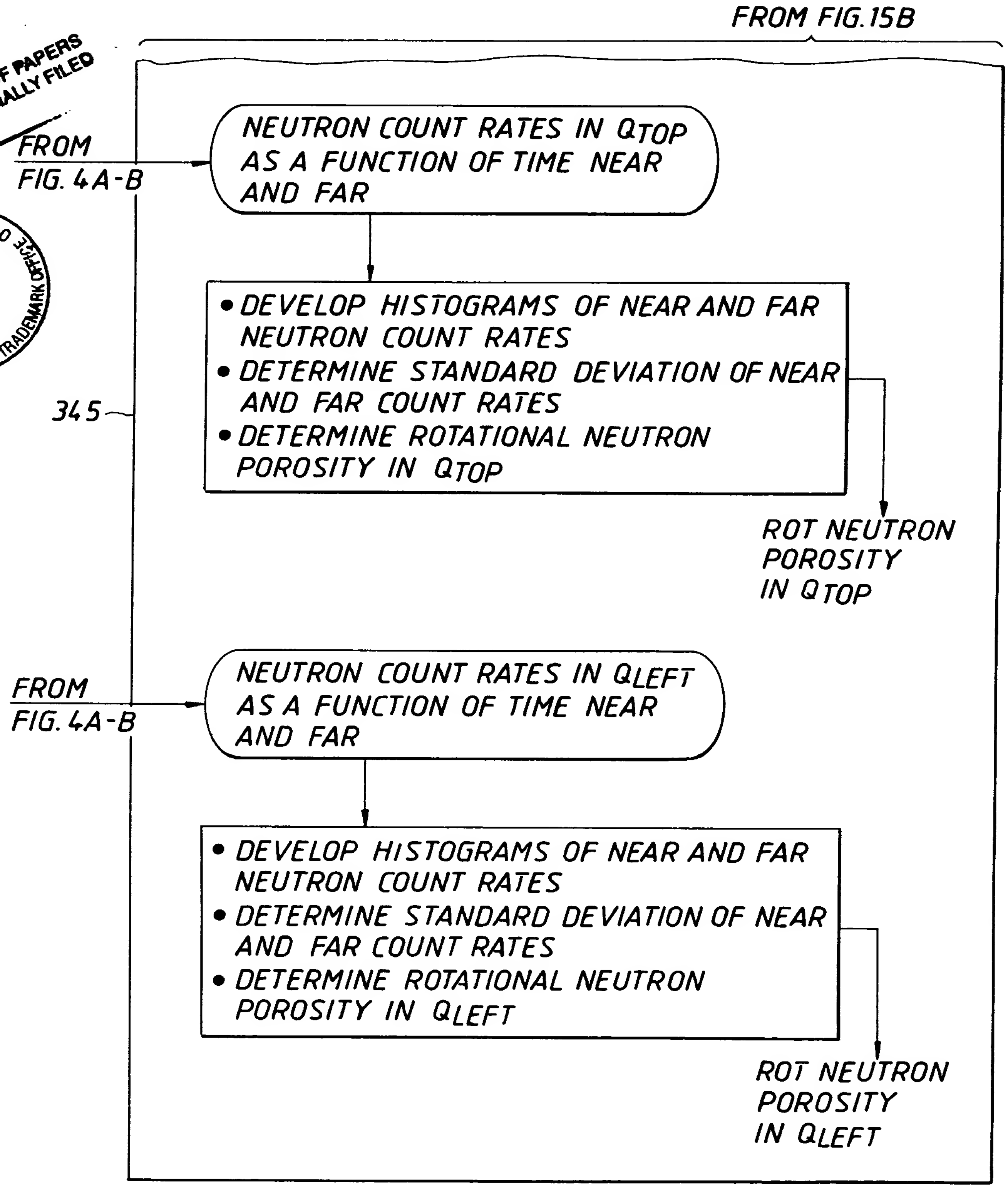

FROM FIG.15A
FROM FIG.4A-B
NEUTRON COUNT RATES IN QBOT AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN QBOT
ROT NEUTRON POROSITY IN QBOT
345
FROM FIG.4A-B
NEUTRON COUNT RATES IN QRIGHT AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN QRIGHT
ROT NEUTRON POROSITY IN QRIGHT
TO FIG.15C

FIG. 15C


FROM FIG. 15B
FROM FIG. 4A-B
NEUTRON COUNT RATES IN $Q_{TOP}$ AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN $Q_{TOP}$
345
ROT NEUTRON POROSITY IN $Q_{TOP}$
FROM FIG. 4A-B
NEUTRON COUNT RATES IN $Q_{LEFT}$ AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN $Q_{LEFT}$
ROT NEUTRON POROSITY IN $Q_{LEFT}$

Application Serial No.: 09/960,445
Docket No.: 19.0302
Title: Method of Kick Detection and Cuttings Bed Buildup Detection using a Drilling Tool
Inventors: Gzara et al.
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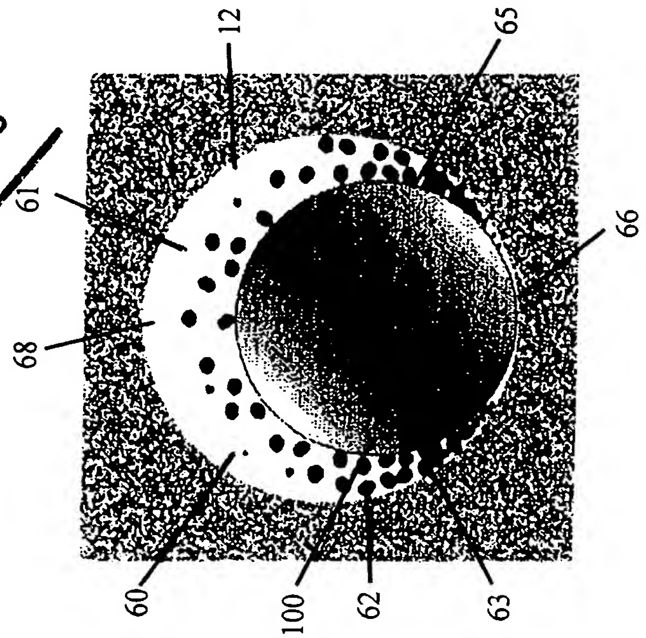


FIG. 16B

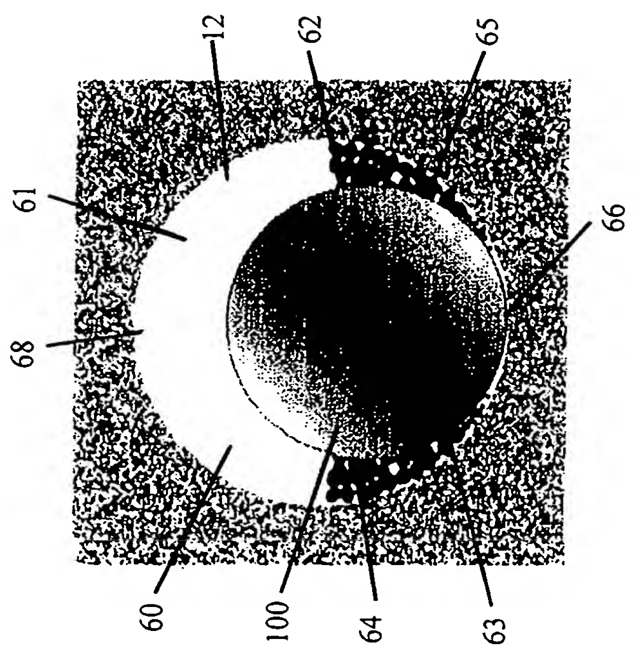


FIG. 16A

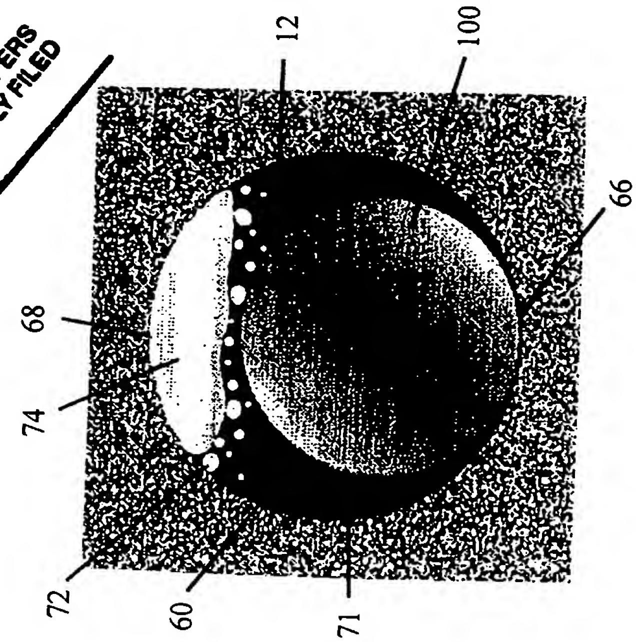


FIG. 17B

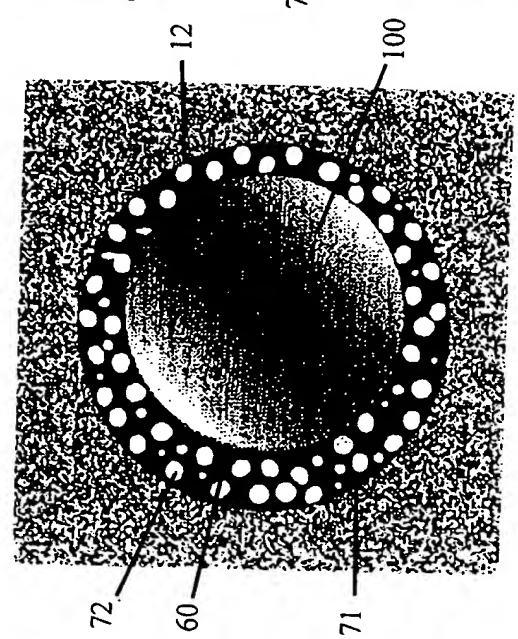


FIG. 17A